SuperKEKB injection meeting

- Simulation of double-peak longitudinal structure, and tracking through the dump line
- Initial tracking of BTp and comparison to ring acceptance
- Effect of transverse wake fields in BTe

FILES I USED/HAVE:

FOR ELECTRONS:

SAD deck file from sector-A to the injection point of HER:

https://kds.kek.jp/event/52845/

"Linac-BTe QAD4E off Case 1" is the **current optics with** R56(Jarc)=0".

I ALSO HAVE: rfg-linac-bte_JarcR56_0_bte-Arc0_R56-0.7_BT.sad. R56(Jarc)=0.7". **New optics?**

FOR POSITRONS: **https://kds.kek.jp/event/56992/** **(NEW)**

I have some file that goes from RTL to injection

linac-btp_BH...1202.sad

linac-btp.sad

Important indicos:

SAD Files: https://kds.kek.jp/event/52845/

https://kds.kek.jp/event/56992/

DESY-KEK-CERN meeting: https://indico.desy.de/event/50139/

Last meeting:

Actions:

- Understand 2-peak longitudinal and transverse distributions, by accounting for transverse wake fields in simulations. Compare to measurements shown by Kamitani-san (Andrea A)
- Try to get gun geometry and reproduce simulations until the first chicane (Andrea L, all)
- Next meeting end of July 2025 or whenever new results available
- Next KEK beam studies planned for Oct 20 – Nov 5 2025

ビーム力学の基礎（第 3 回): https://kds.kek.jp/event/55976/

ICG summary 2025.May-June: https://kds.kek.jp/event/55934/

DESY.

SuperKEKB injection meeting

- **Effect of transverse wake fields in BTe**

In OCELOT: The `Wake` class models the effect of the wake field on a particle beam by applying a series of kicks calculated from a Taylor expansion of the longitudinal wake function.

We use the same format of the wakes as implemented in ASTRA:

The implementation of wake fields in Astra is based on a second order Taylor expansion of the longitudinal wake in the transverse coordinates

$$h_w(u_s, v_s, u_o, v_o, s) = \begin{bmatrix} 1 \\ u_s \\ v_s \\ u_o \\ v_o \end{bmatrix}^t \begin{bmatrix} h_{00}(s) & h_{01}(s) & h_{02}(s) & h_{03}(s) & h_{04}(s) \\ 0 & h_{11}(s) & h_{12}(s) & h_{13}(s) & h_{14}(s) \\ 0 & h_{12}(s) & h_{22}(s) & h_{23}(s) & h_{24}(s) \\ 0 & h_{13}(s) & h_{23}(s) & h_{33}(s) & h_{34}(s) \\ 0 & h_{14}(s) & h_{24}(s) & h_{34}(s) & -h_{33}(s) \end{bmatrix} \begin{bmatrix} 1 \\ u_s \\ v_s \\ u_o \\ v_o \end{bmatrix} . \quad (9)$$

This approach fulfilles Eq. (7). The transverse components are uniquely related to the longitudinale wake by causality and Panofsky-Wenzel-Theorem:

$$h_u(u_s, v_s, u_o, v_o, s) = h_{03}^{(i)}(s) + 2h_{13}^{(i)}(s)u_s + 2h_{23}^{(i)}(s)v_s + 2h_{33}^{(i)}(s)u_o + 2h_{34}^{(i)}(s)v_o , \quad (10)$$

$$h_v(u_s, v_s, u_o, v_o, s) = h_{04}^{(i)}(s) + 2h_{14}^{(i)}(s)u_s + 2h_{24}^{(i)}(s)v_s + 2h_{34}^{(i)}(s)u_o - 2h_{33}^{(i)}(s)v_o , \quad (11)$$

with the integrated coefficient functions

$$h_{\alpha\beta}^{(i)}(s) = -\int_{-\infty}^{s} h_{\alpha\beta}(x)dx . \quad (12)$$

Special cases for geometries with symmetry of revolution are the monopole and dipole wake. The monopole wake

$$\vec{w}_f(u_s, v_s, u_o, v_o, s) = -h_{00}(s)\vec{e}_w \quad (13)$$

is purely longitudinal and independent on offset parameters. The transverse part of the dipole wake depends linear on the offset of the source particle. Due to symmetry the coefficient functions $h_{13}(s)$ and $h_{24}(s)$ are identical. Therefore the dipole wake functions is

$$\vec{w}_f(u_s, v_s, u_o, v_o, s) = -(u_s\vec{e}_u + v_s\vec{e}_v)2h_{13}^{(i)}(s) - (u_s u_o + v_s v_o)\vec{e}_w 2h_{13}(s) . \quad (14)$$

-M. Dohlus, K. Floettmann, C. Henning, Fast particle tracking with wake fields, Report No. DESY 12-012, 2012.

DESY.

In OCELOT: The `Wake` class models the effect of the wake field on a particle beam by applying a series of kicks calculated from a Taylor expansion of the longitudinal wake function.

We use the same format of the wakes as implemented in ASTRA:

The implementation of wake fields in Astra is based on a second order Taylor expansion of the longitudinal wake in the transverse coordinates

$$h_w(u_s, v_s, u_o, v_o, s) = \begin{bmatrix} 1 \\ u_s \\ v_s \\ u_o \\ v_o \end{bmatrix}^t \begin{bmatrix} h_{00}(s) & h_{01}(s) & h_{02}(s) & h_{03}(s) & h_{04}(s) \\ 0 & h_{11}(s) & h_{12}(s) & h_{13}(s) & h_{14}(s) \\ 0 & h_{12}(s) & h_{22}(s) & h_{23}(s) & h_{24}(s) \\ 0 & h_{13}(s) & h_{23}(s) & h_{33}(s) & h_{34}(s) \\ 0 & h_{14}(s) & h_{24}(s) & h_{34}(s) & -h_{33}(s) \end{bmatrix} \begin{bmatrix} 1 \\ u_s \\ v_s \\ u_o \\ v_o \end{bmatrix} . \quad (9)$$

This approach fulfilles Eq. (7). The transverse components are uniquely related to the longitudinale wake by causality and Panofsky-Wenzel-Theorem:

$$h_u(u_s, v_s, u_o, v_o, s) = h_{03}^{(i)}(s) + 2h_{13}^{(i)}(s)u_s + 2h_{23}^{(i)}(s)v_s + 2h_{33}^{(i)}(s)u_o + 2h_{34}^{(i)}(s)v_o \, , \quad (10)$$

$$h_v(u_s, v_s, u_o, v_o, s) = h_{04}^{(i)}(s) + 2h_{14}^{(i)}(s)u_s + 2h_{24}^{(i)}(s)v_s + 2h_{34}^{(i)}(s)u_o - 2h_{33}^{(i)}(s)v_o \, , \quad (11)$$

with the integrated coefficient functions

$$h_{\alpha\beta}^{(i)}(s) = -\int_{-\infty}^{s} h_{\alpha\beta}(x)dx \, . \quad (12)$$

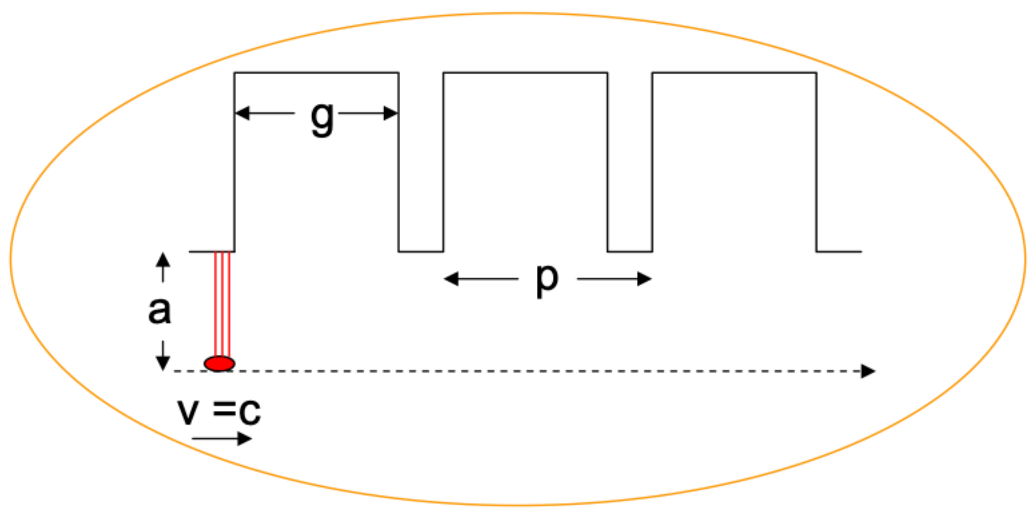
Special cases for geometries with symmetry of revolution are the monopole and dipole wake. The monopole wake

$$\vec{w}_f(u_s, v_s, u_o, v_o, s) = -h_{00}(s)\vec{e}_w \quad (13)$$

-M. Dohlus, K. Floettmann, C. Henning, Fast particle tracking with wake fields, Report No. DESY 12-012, 2012.

Pretty straightforward for longitudinal wakefields

Which we already had with bane formula for a periodic structure :



$$W(s) = \frac{Z_0 c}{\pi a^2} \exp\left(-\sqrt{s/s_1}\right) \quad , \quad (12)$$

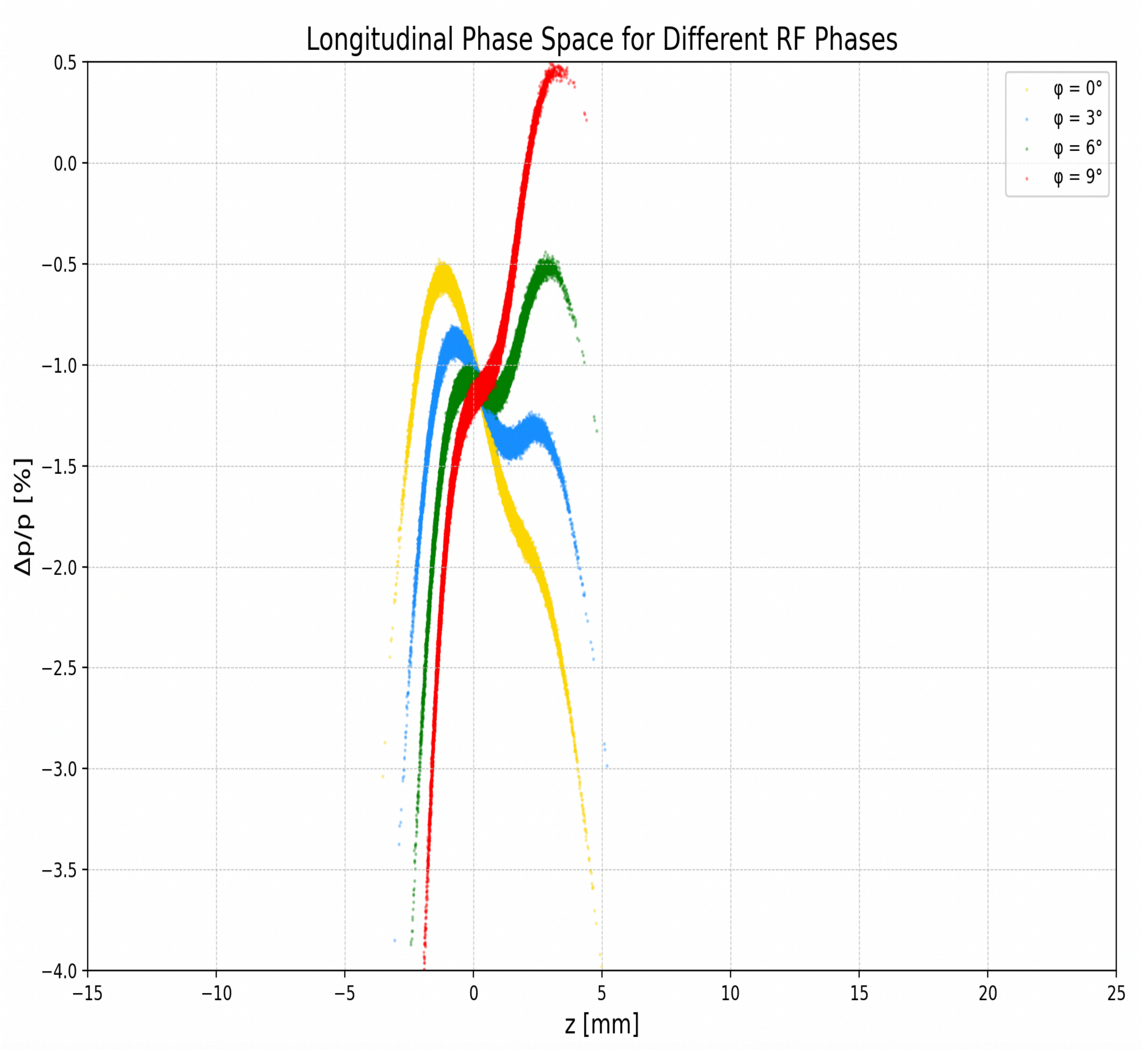
with

$$s_1 = 0.41 \frac{a^{1.8} g^{1.6}}{p^{2.4}} \, . \quad (13)$$

-SLAC-PUB-11829

DESY.

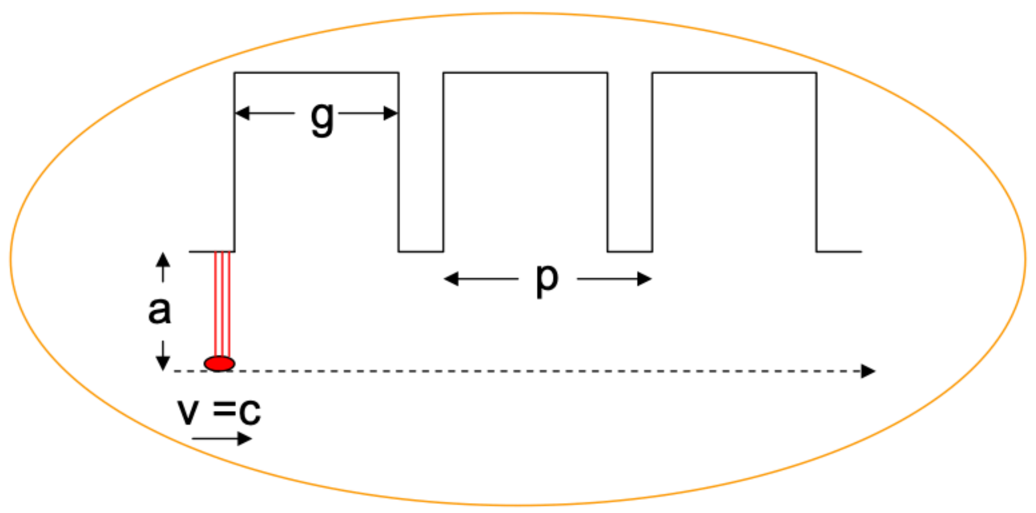
In OCELOT: The `Wake` class models the effect of the wake field on a particle beam by applying a series of kicks calculated from a Taylor expansion of the longitudinal wake function.



*This plot I've shown before

Pretty straightforward for longitudinal wakefields

Which we already had with bane formula for a periodic structure :



$$W(s) = \frac{Z_0 c}{\pi a^2} \exp\left(-\sqrt{s/s_1}\right) \quad , \tag{12}$$

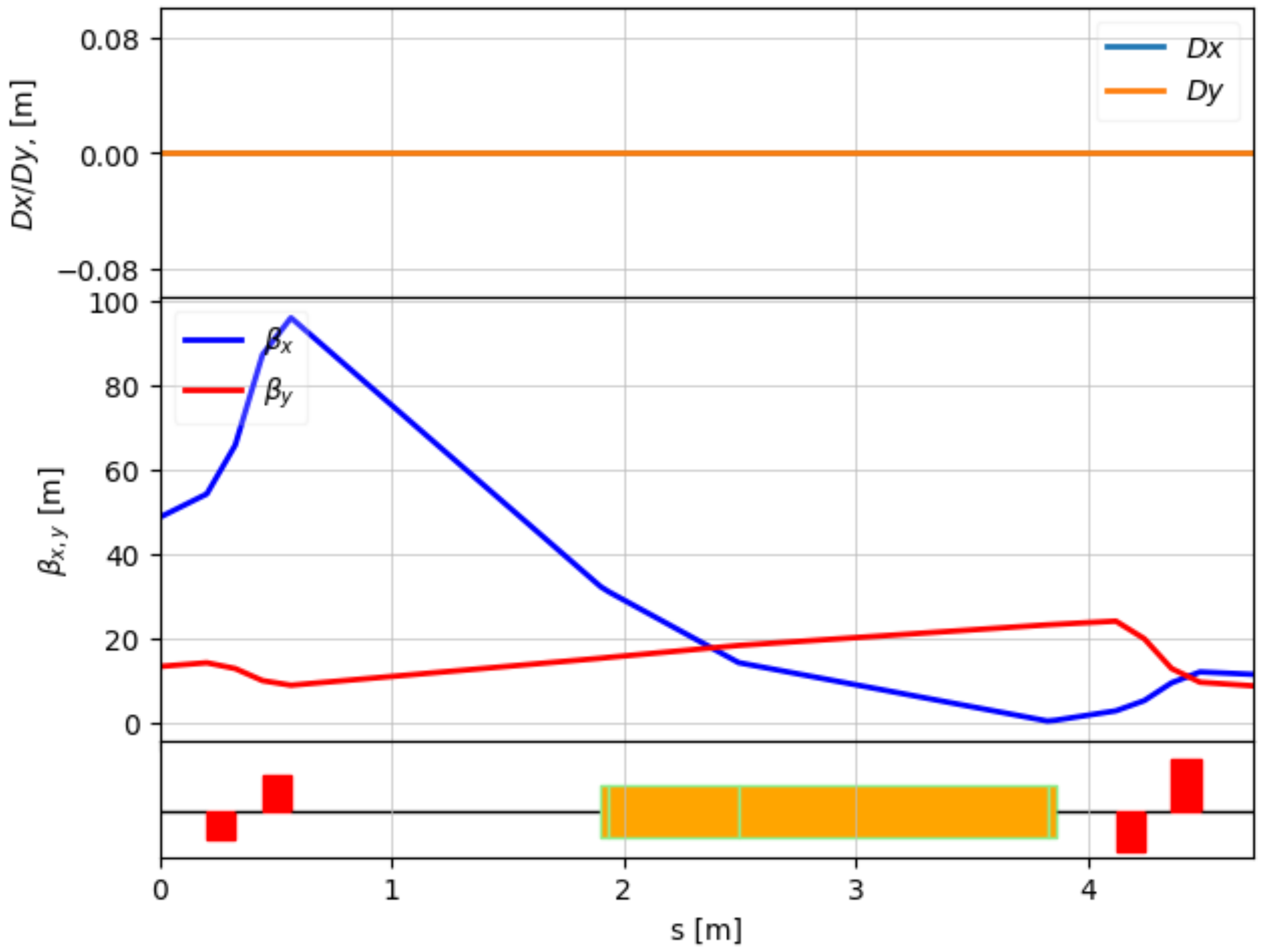
with

$$s_1 = 0.41 \frac{a^{1.8} g^{1.6}}{p^{2.4}} \quad . \tag{13}$$

-SLAC-PUB-11829

DESY.

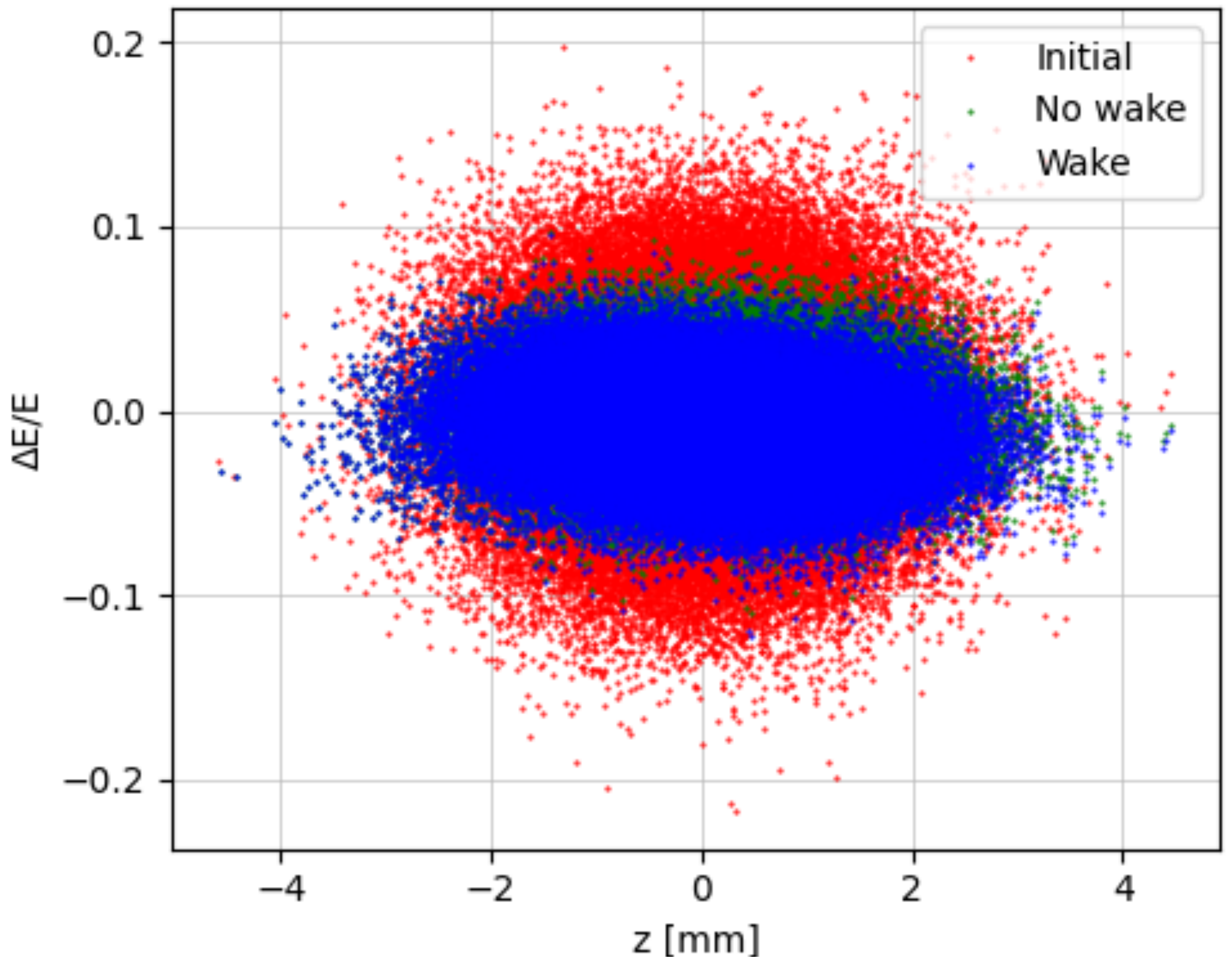
All next plots are just for the beginning of SuperKEKB linac:

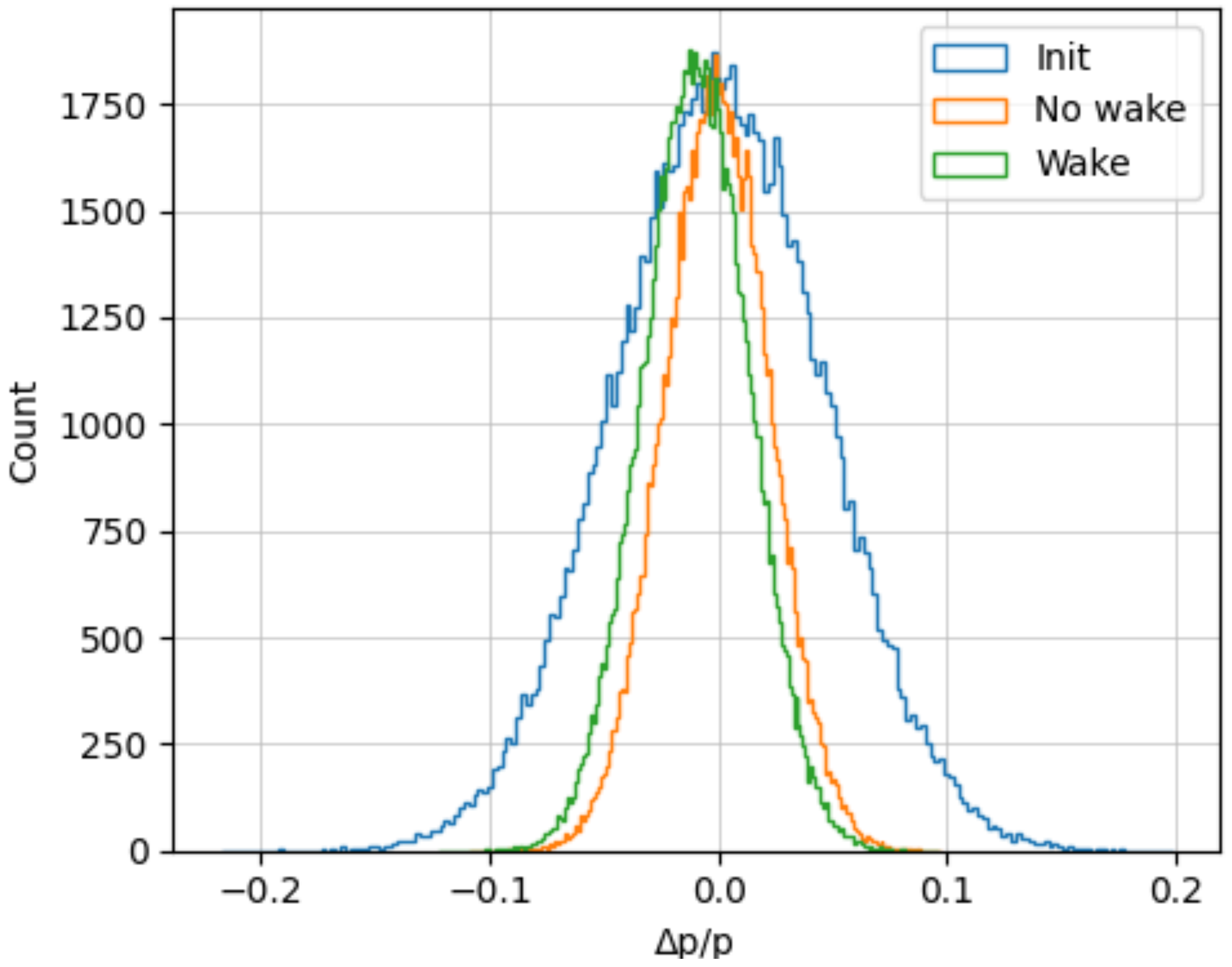


Benchmark

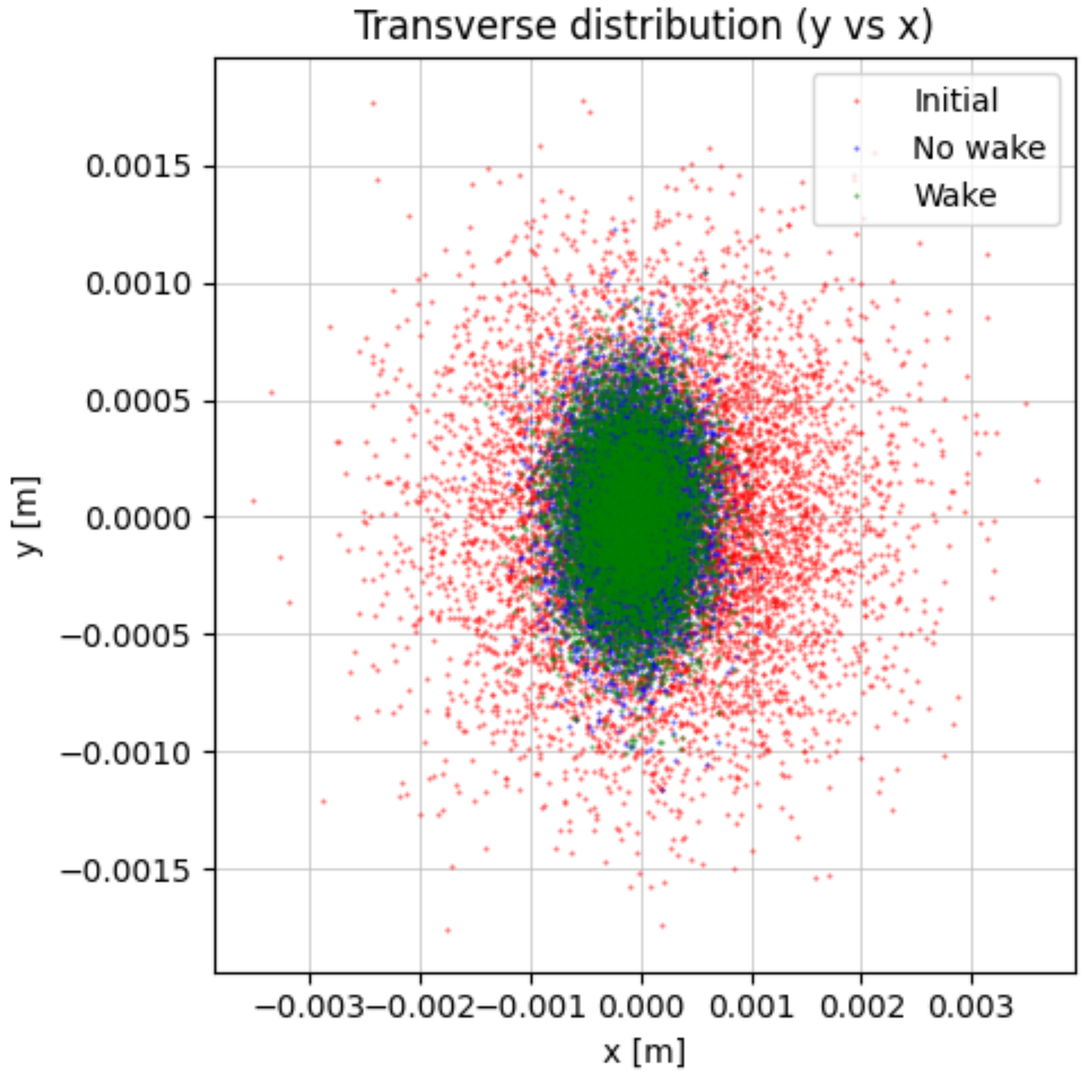
DESY.

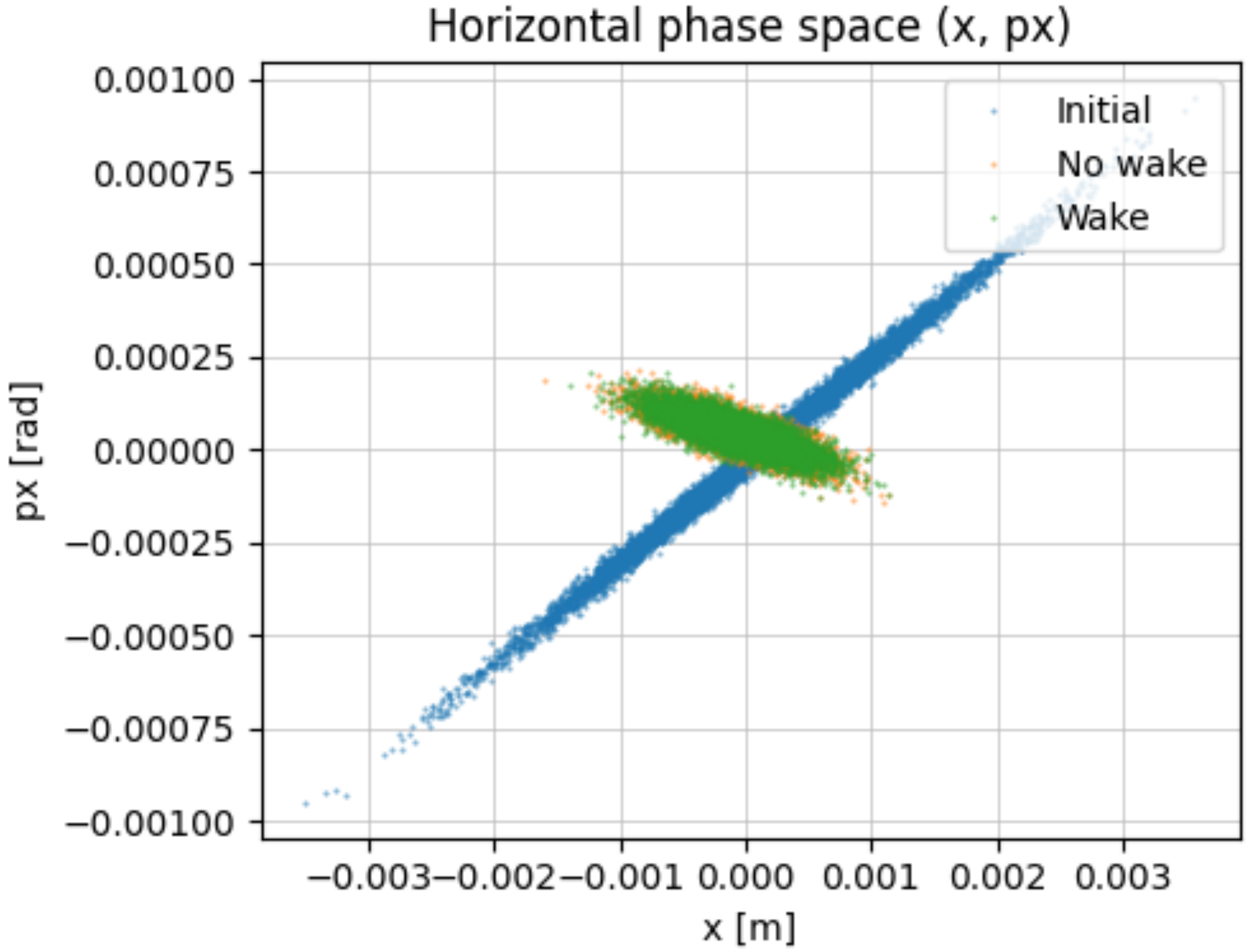
With longitudinal wakefield only:

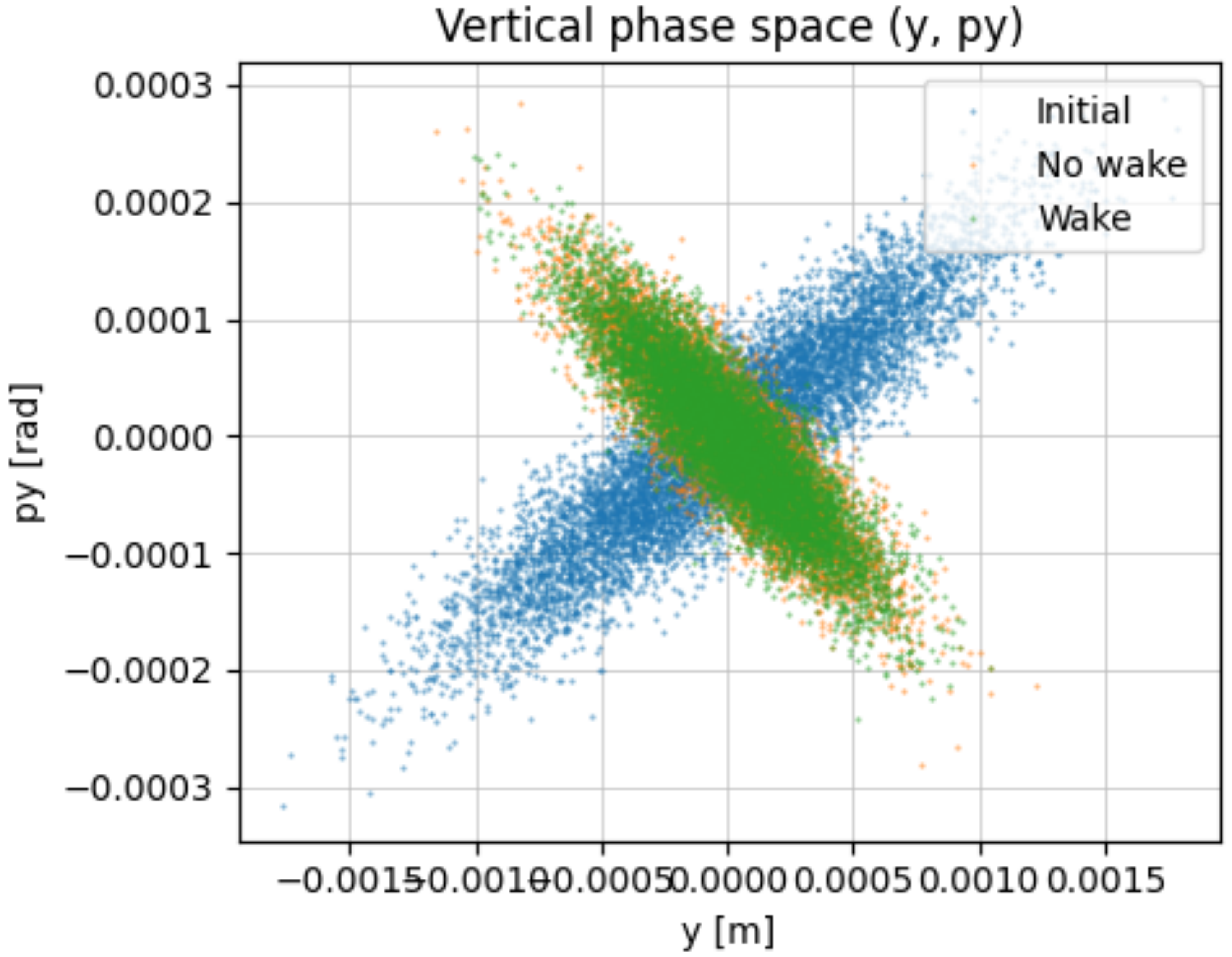




Benchmark

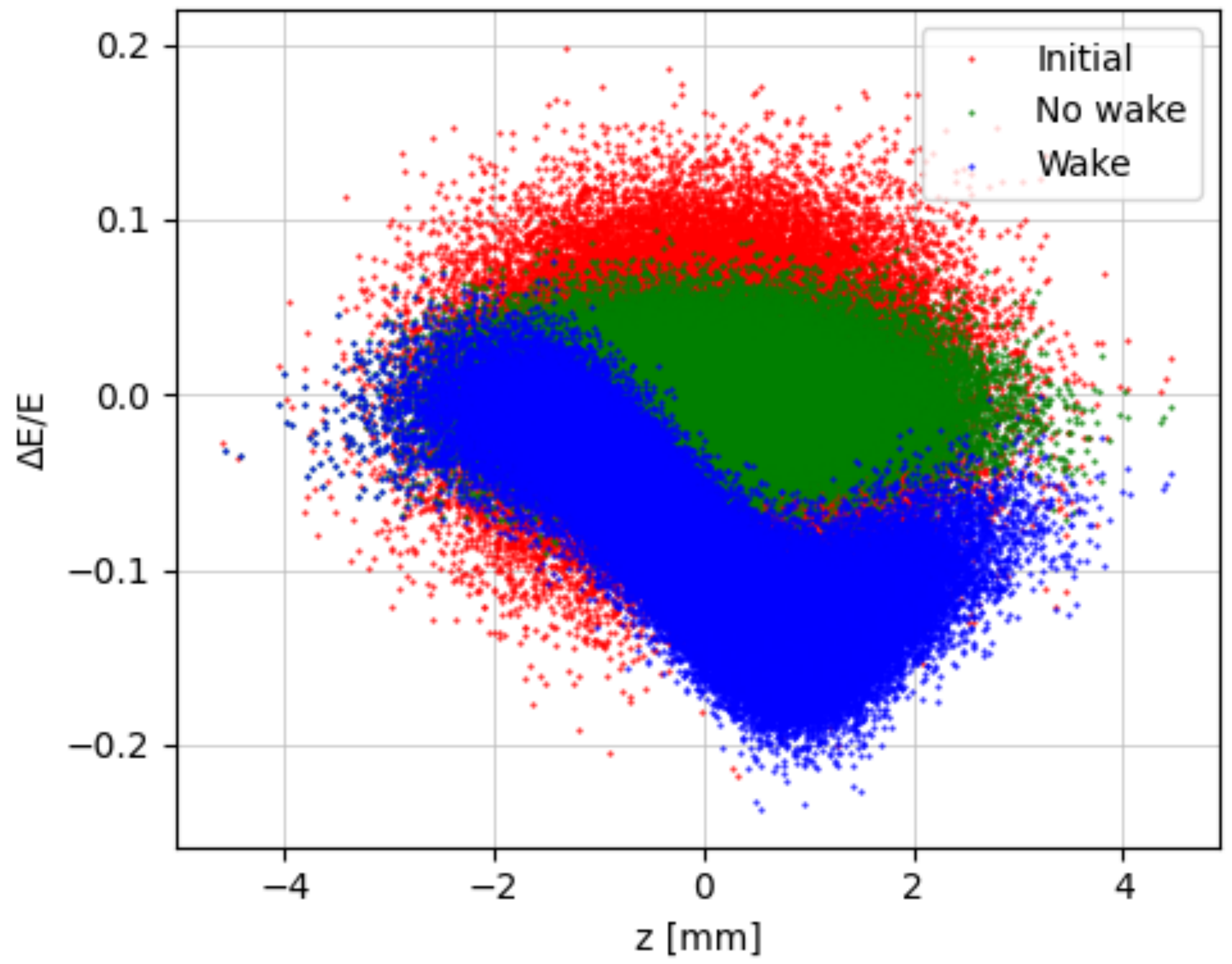


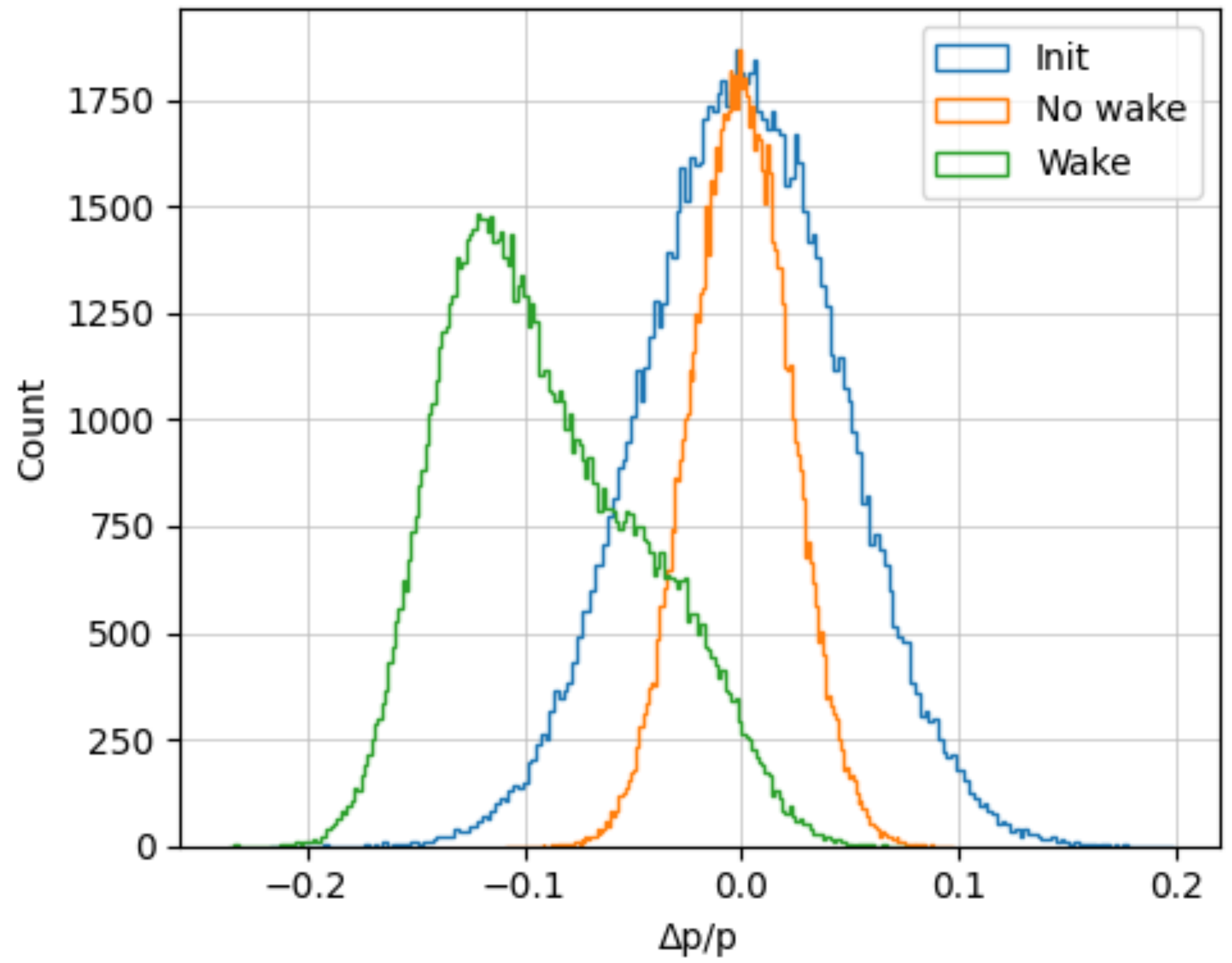




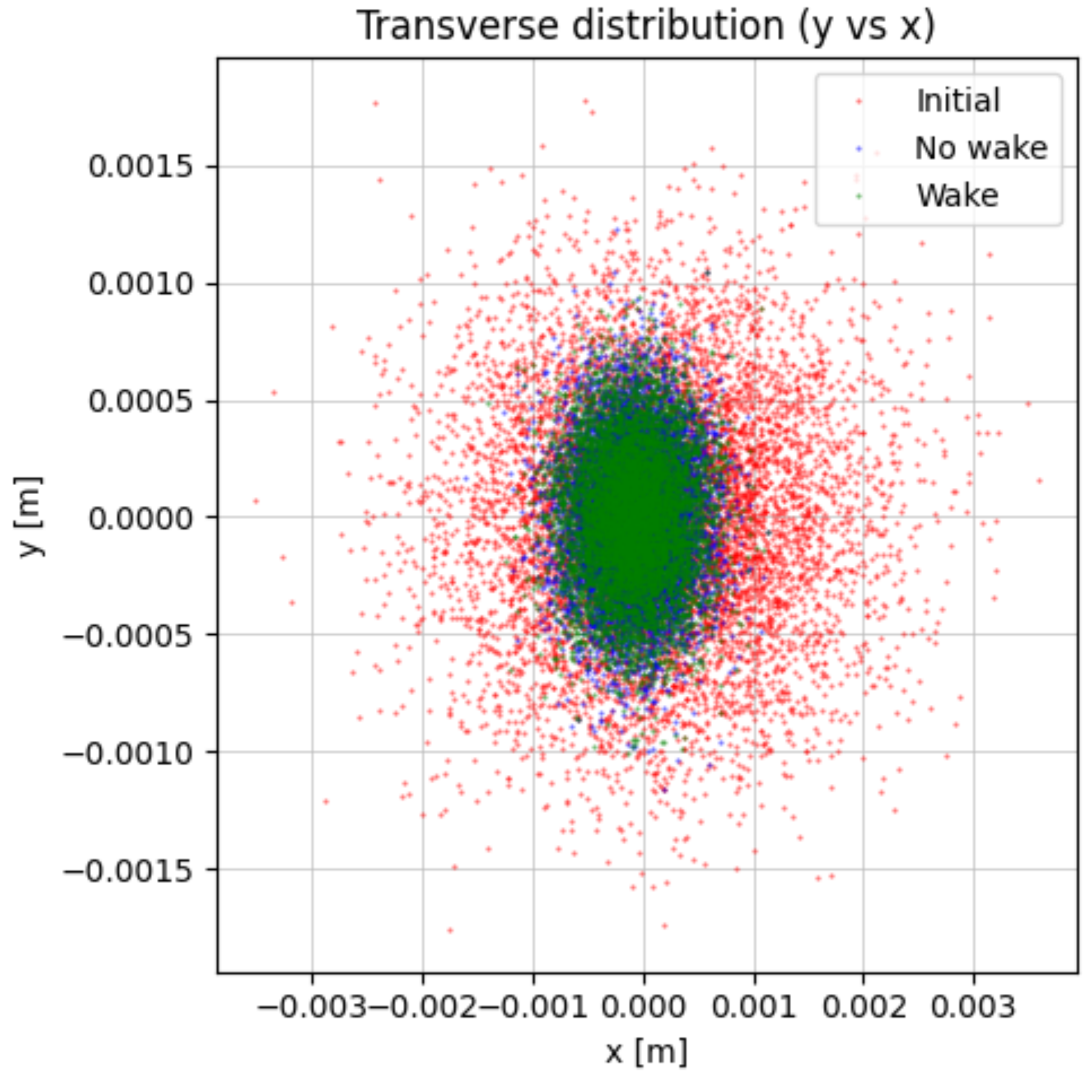
DESY.

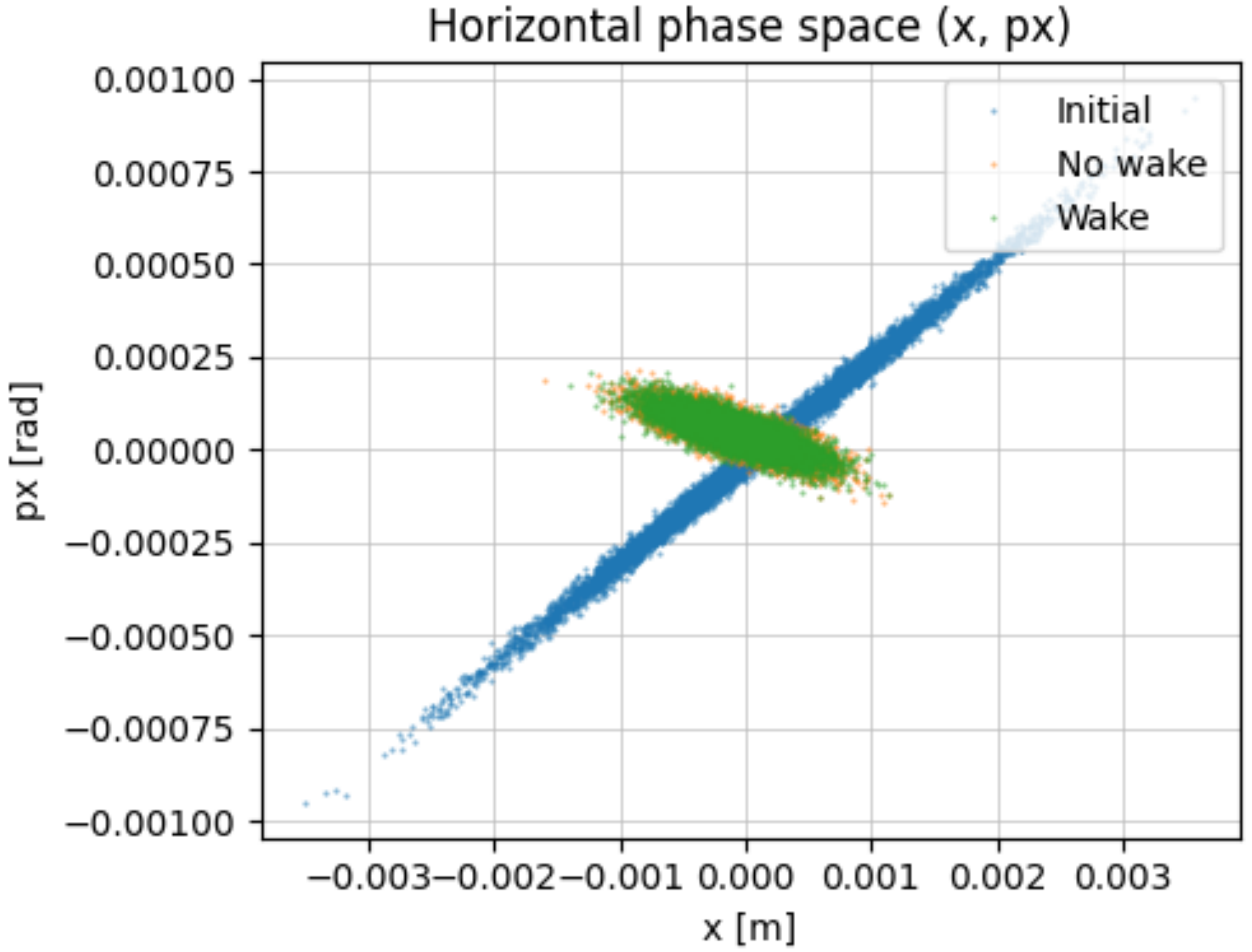
With longitudinal wakefield only: if we increase charge to 30.0e-9 C

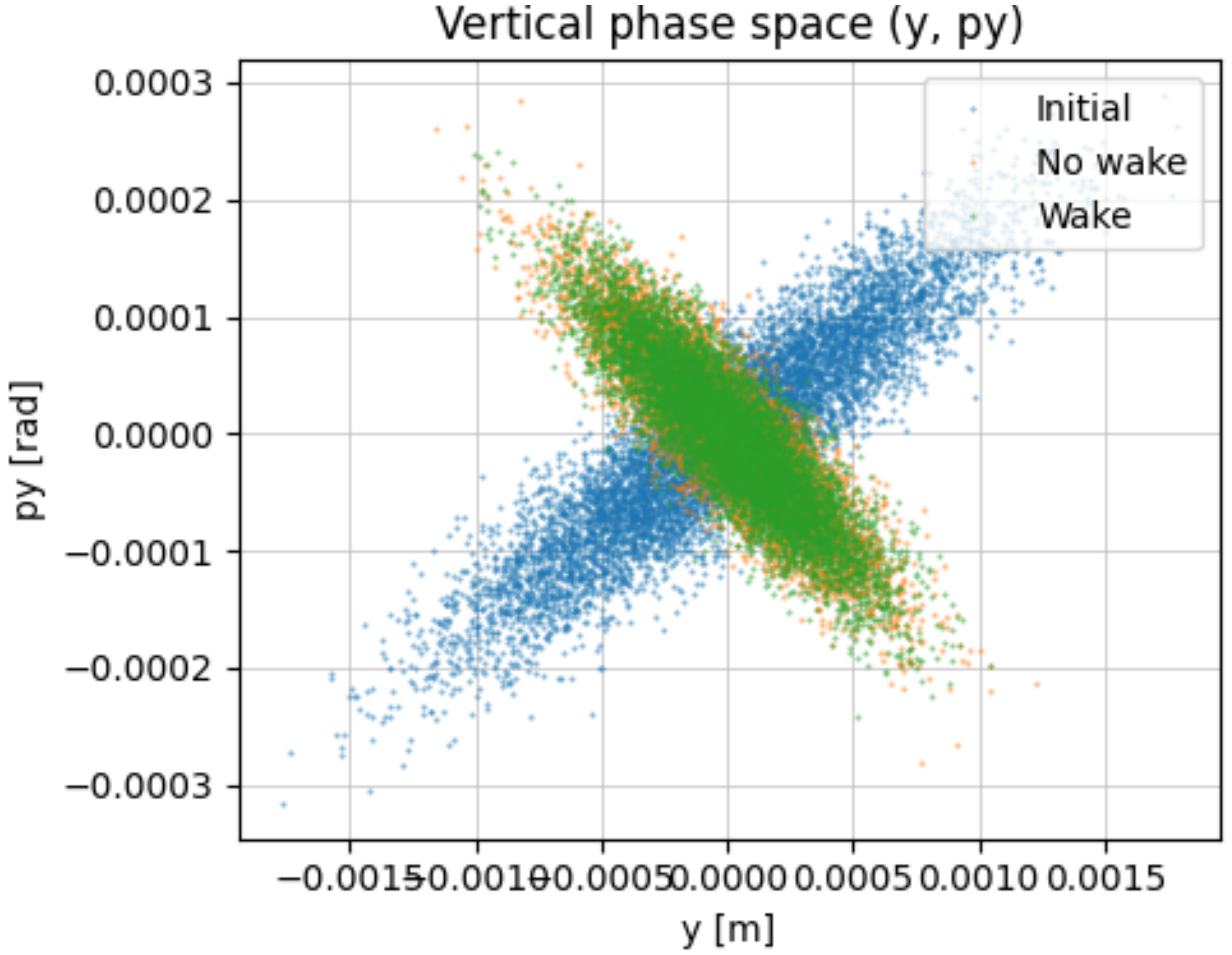




Benchmark







DESY.

A small note about transverse modes

Let's look at the wakefield components. Let's start with the expression above:

$$w_z(x_s, y_s, x_o, y_o, s) = \begin{bmatrix} 1 \\ x_s \\ y_s \\ x_o \\ y_o \end{bmatrix}^T \begin{bmatrix} h_{00}(s) & h_{01}(s) & h_{02}(s) & h_{03}(s) & h_{04}(s) \\ 0 & h_{11}(s) & h_{12}(s) & h_{13}(s) & h_{14}(s) \\ 0 & h_{12}(s) & -h_{11}(s) & h_{23}(s) & h_{24}(s) \\ 0 & h_{13}(s) & h_{23}(s) & h_{33}(s) & h_{34}(s) \\ 0 & h_{14}(s) & h_{24}(s) & h_{34}(s) & -h_{33}(s) \end{bmatrix} \begin{bmatrix} 1 \\ x_s \\ y_s \\ x_o \\ y_o \end{bmatrix};$$

Expand the result of the multiplication:

$$\begin{aligned} w_z(x_s, y_s, x_o, y_o, s) = h_{00}(s) + h_{03}(s)x_o + h_{33}(s)x_o^2 + h_{01}(s)x_s + 2h_{13}(s)x_o x_s + h_{11}(s)x_s^2 + h_{04}(s)y_o + \\ 2h_{34}(s)x_o y_o + 2h_{14}(s)x_s y_o - h_{33}(s)y_o^2 + h_{02}(s)y_s + 2h_{23}(s)x_o y_s + \\ 2h_{12}(s)x_s y_s + 2h_{24}(s)y_o y_s - h_{11}(s)y_s^2 \end{aligned}$$

Using Panofsky-Wenzel-Theorem the transverse components are:

$$\frac{\partial}{\partial s} w_y(x_s, y_s, x_o, y_o, s) = -\frac{\partial}{\partial y_o} w_z(x_s, y_s, x_o, y_o, s) = -(h_{04}(s) + 2h_{34}(s)x_o + 2h_{14}(s)x_s - 2h_{33}(s)y_o + 2h_{24}(s)y_s)$$

where $-h_{04}(s)$ monopole transverse component, $-h_{24}(s)$ - dipole component, $h_{33}(s)$ - quadrupole component,

$$\frac{\partial}{\partial s} w_x(x_s, y_s, x_o, y_o, s) = -\frac{\partial}{\partial x_o} w_z(x_s, y_s, x_o, y_o, s) = -(h_{03}(s) + 2h_{33}(s)x_o + 2h_{13}(s)x_s + 2h_{34}(s)y_o + 2h_{23}(s)y_s)$$

where $h_{03}(s)$ - monopole transverse component, $-h_{13}(s)$ - dipole component, $-h_{33}(s)$ - quadrupole component.

Integral forms:

$$w_y(x_s, y_s, x_o, y_o, s) = -\int_{-\infty}^{s} \frac{\partial}{\partial y_o} w_z(x_s, y_s, x_o, y_o, s')ds'$$

$$w_x(x_s, y_s, x_o, y_o, s) = -\int_{-\infty}^{s} \frac{\partial}{\partial x_o} w_z(x_s, y_s, x_o, y_o, s')ds'$$

But our transverse wakefield doesn't come from this theorem:

- **Longitudinal monopole wake**

$$W_{\parallel}(s) = \frac{Z_0 c}{\pi a^2} \exp\left(-\sqrt{\tfrac{s}{s_1}}\right), \quad s_1 = 0.41 \frac{a^{1.8} g^{1.6}}{p^{2.4}}.$$

- **Transverse dipole wake**

$$W_x(s) = \frac{4 Z_0 c s_2}{\pi a^4} \left[1 - \left(1 + \sqrt{\tfrac{s}{s_2}}\right) \exp\left(-\sqrt{\tfrac{s}{s_2}}\right)\right], \quad s_2 = 0.17 \frac{a^{1.79} g^{0.38}}{p^{1.17}}.$$

These are *not derived by Panofsky–Wenzel* from a single w_z. Instead, they were obtained by **numerical simulations** of periodic accelerating structures and then fitted to simple analytic forms.

-SLAC-PUB-11829

Hence, we need to take the derivative of the the function, multiply by 0.5, and give it as h13 and h24.

$$\boxed{\frac{d}{ds} W_x^{(1)}(s) = -2\, h_{13}(s) \quad \Rightarrow \quad h_{13}(s) = -\frac{1}{2} \frac{d}{ds} W_x^{(1)}(s).}$$

DESY.

Theory vs. Simulation

Theory (Bane–Stupakov model)

$$W_x(s) \;=\; \frac{4Z_0 c\, s_2}{\pi a^4}\left[1-\left(1+\sqrt{s s_2}\right)e^{-\sqrt{s/s_2}}\right],$$

with

$$s_2 = 0.17\,\frac{a^{1.79}g^{0.38}}{p^{1.17}},$$

where Z_0 is the impedance of free space, c the speed of light, and s the distance behind the driving particle.

Implementation in OCELOT

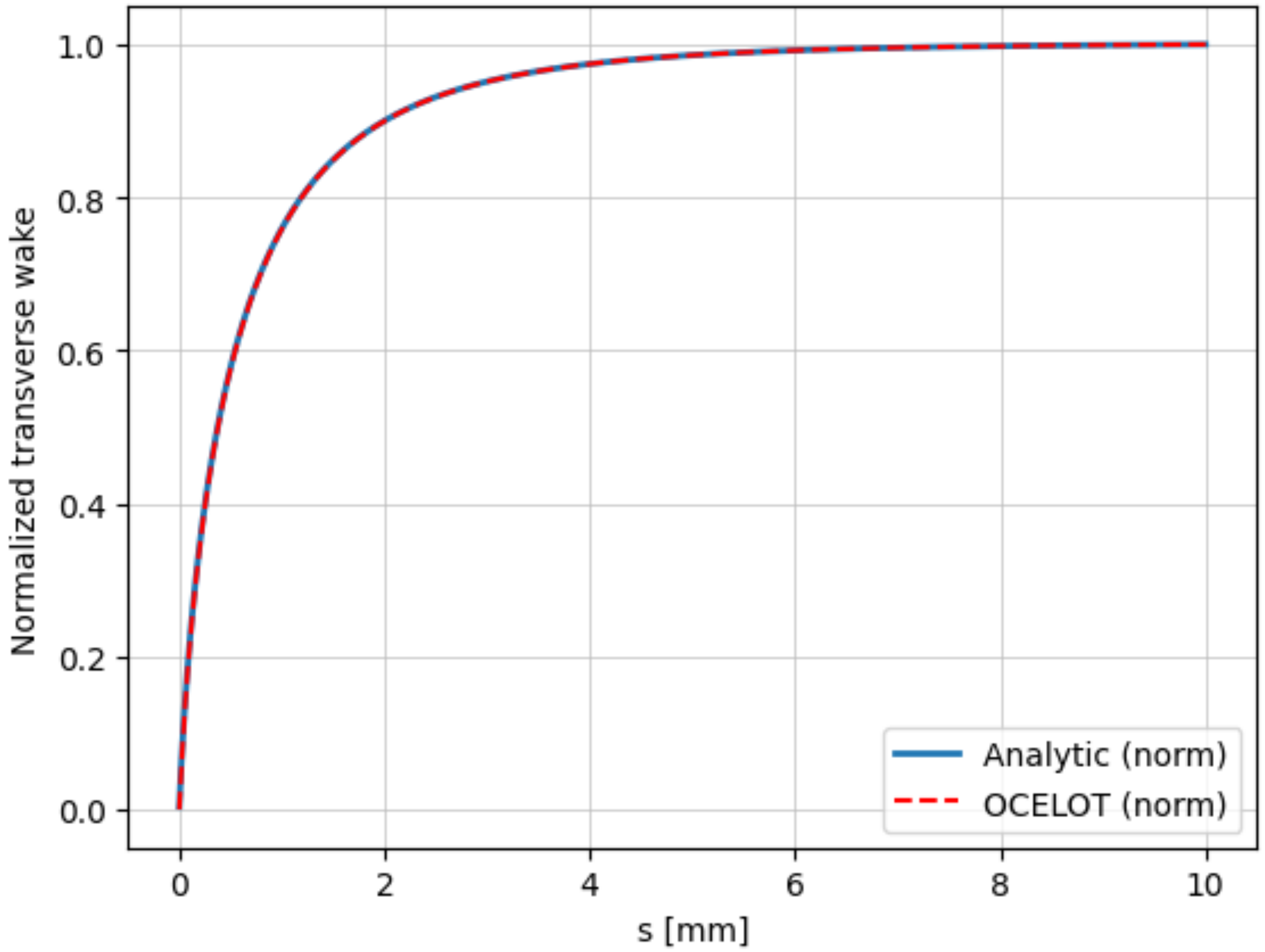
- Wakefields are supplied as expansion coefficients of the longitudinal wake.
- Transverse wakes are computed internally via the Panofsky–Wenzel theorem:

$$\nabla_\perp W_\parallel(s) \;=\; -\frac{\partial}{\partial s}W_\perp(s).$$

- The dipole wake was implemented in the `nm=04` slot of the WakeTable.

Comparison

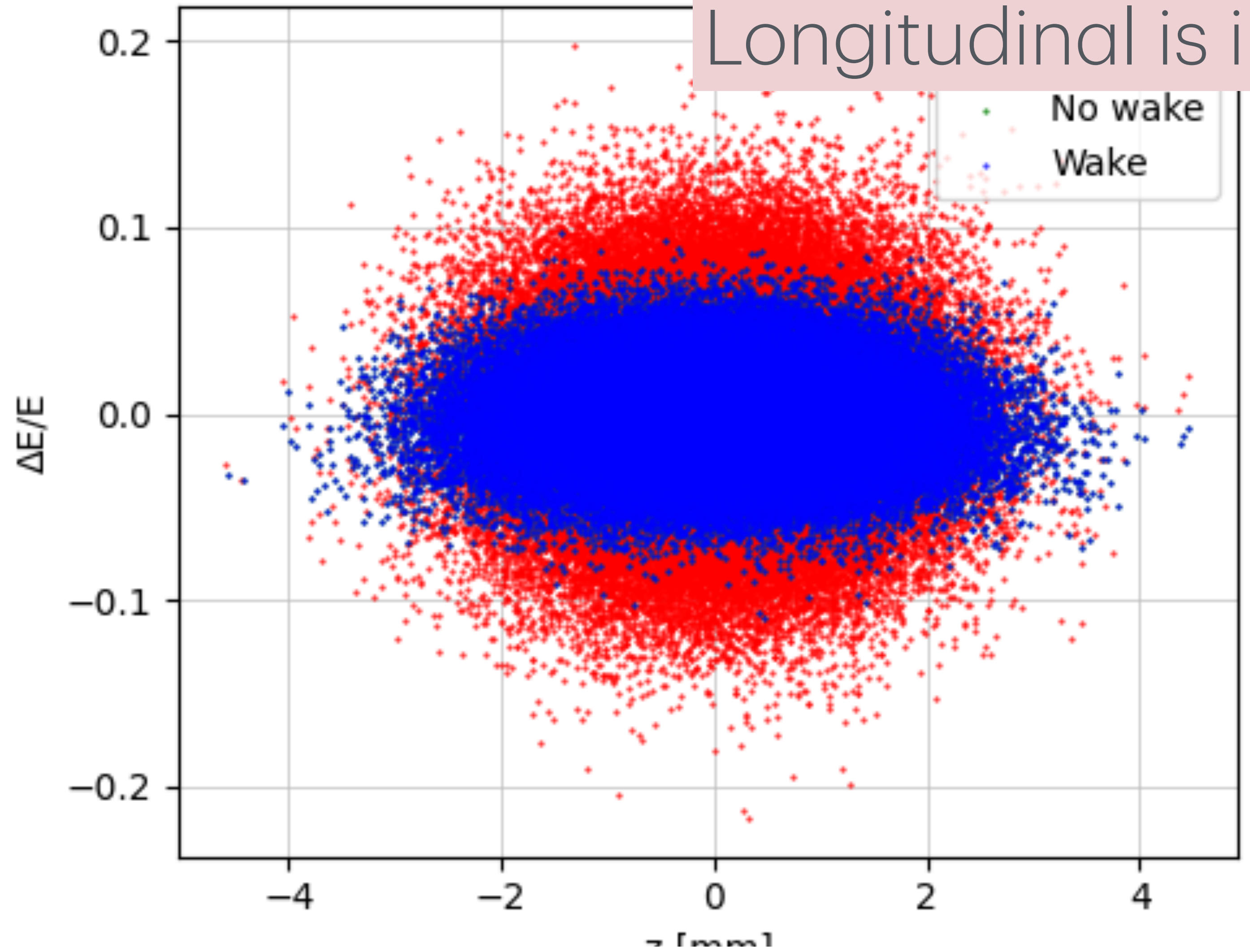
- Analytic curve (blue): Bane–Stupakov model.
- Simulation (red): extracted with `get_dipole_wake()`.
- After correcting for sign convention, both curves overlap perfectly.

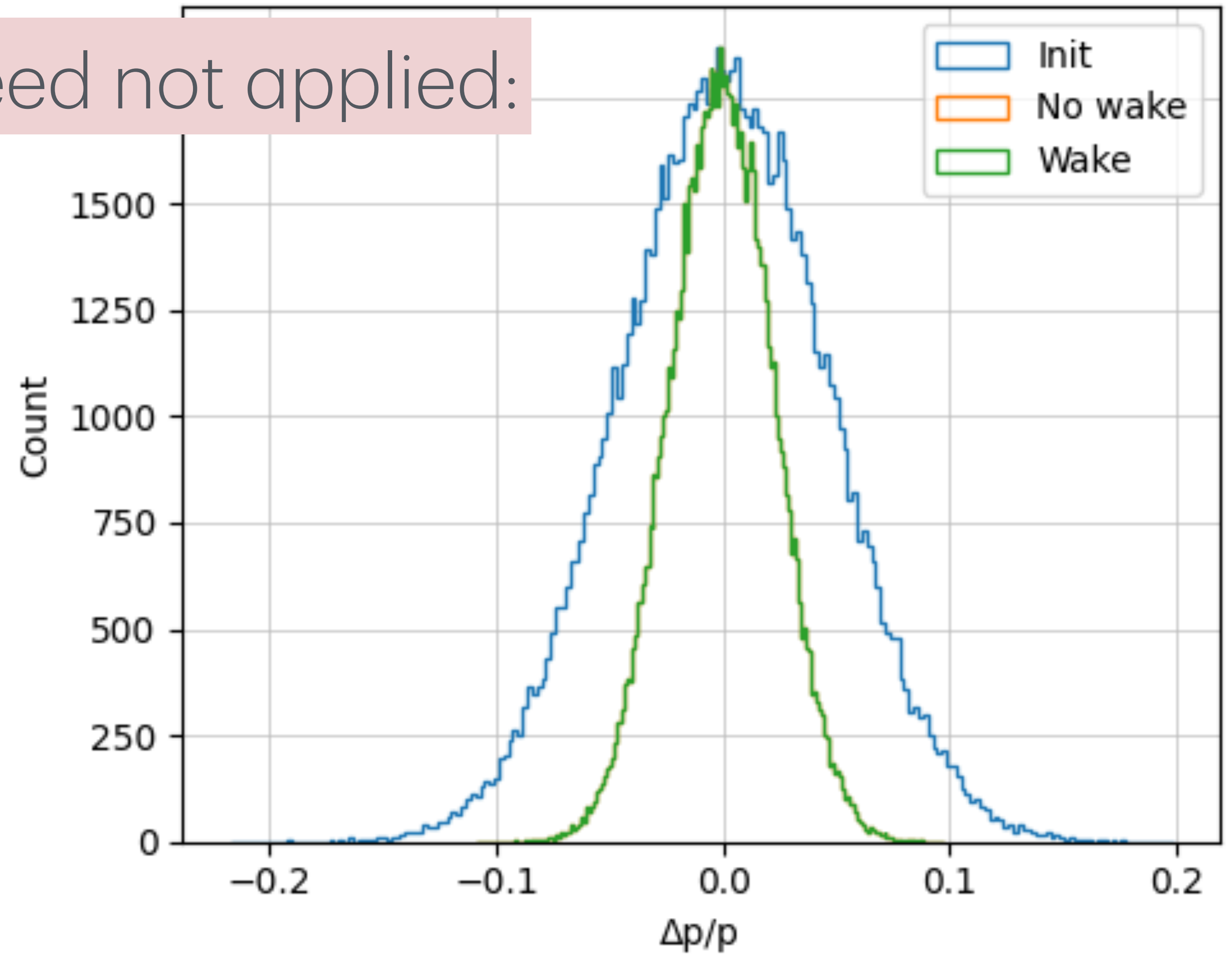


DESY.

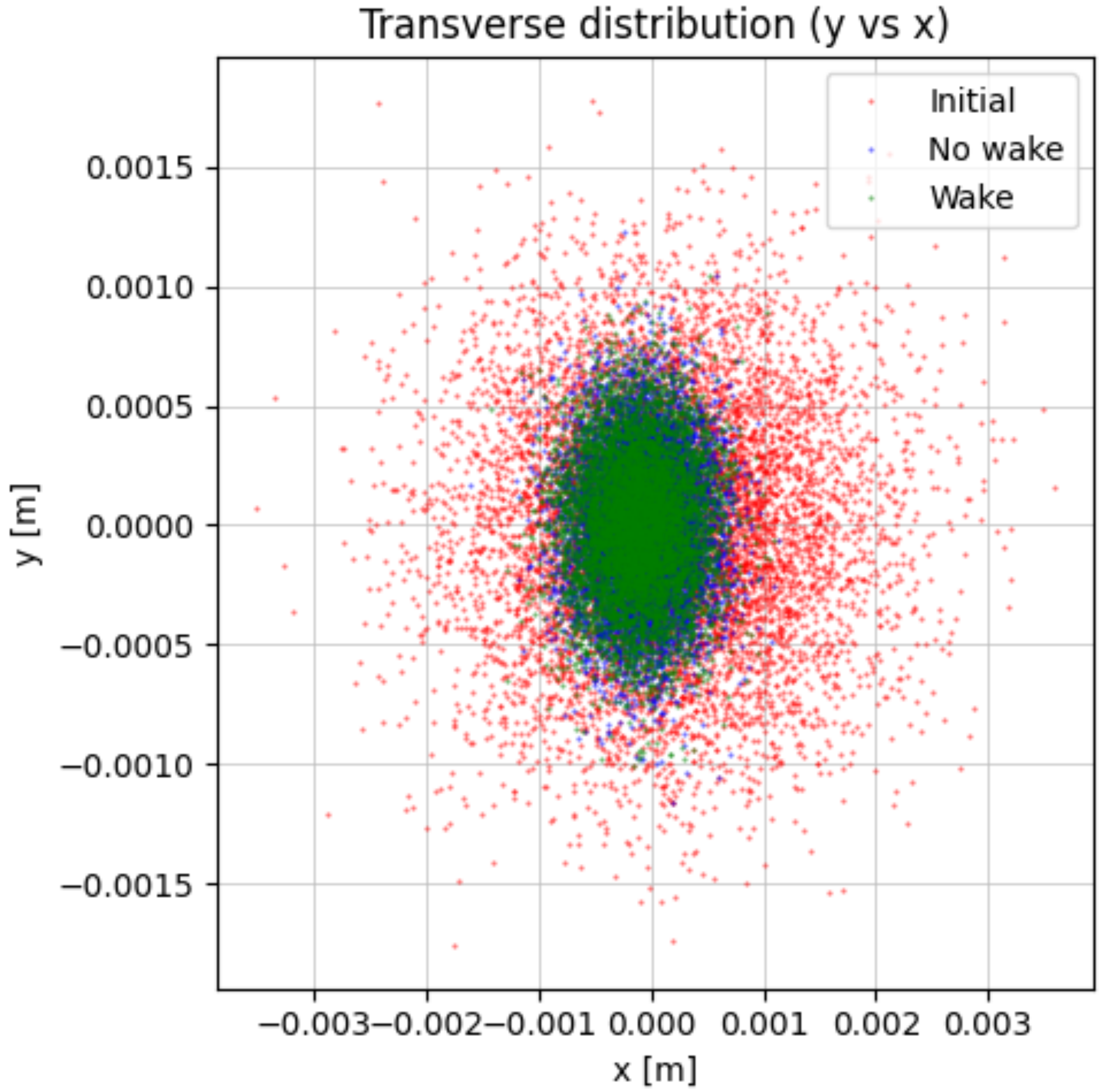
- And now the plots become:

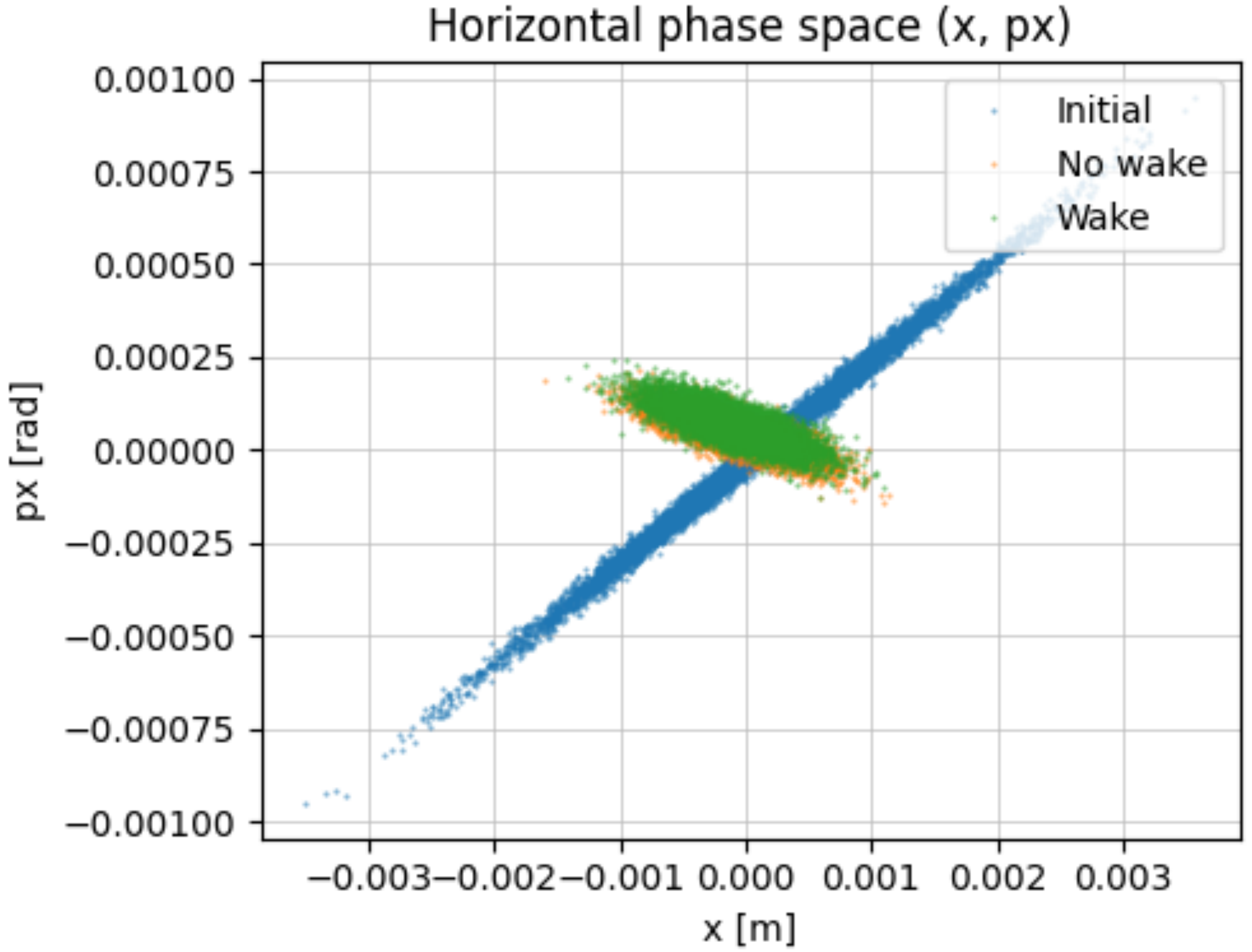
Longitudinal is indeed not applied:

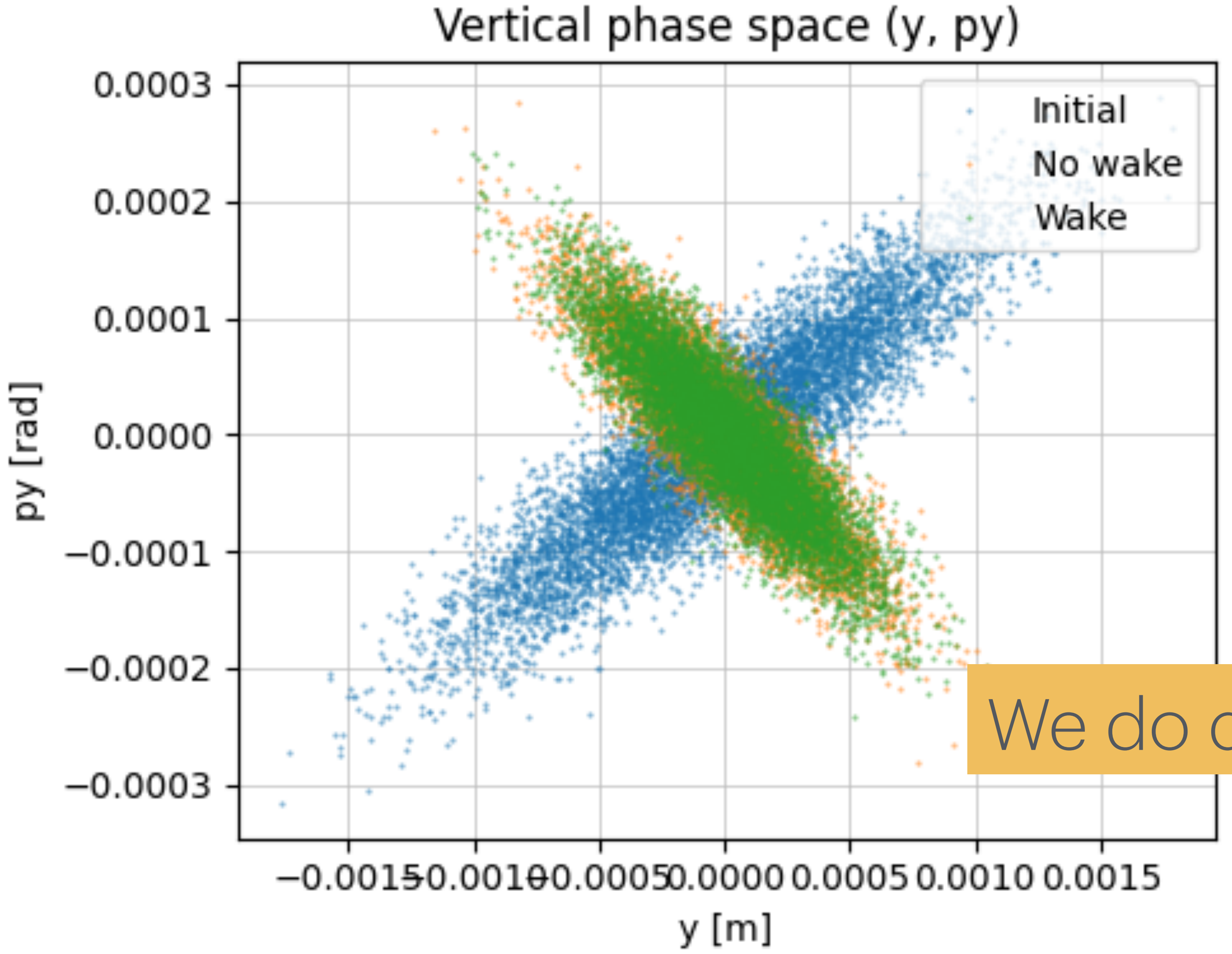




Benchmark





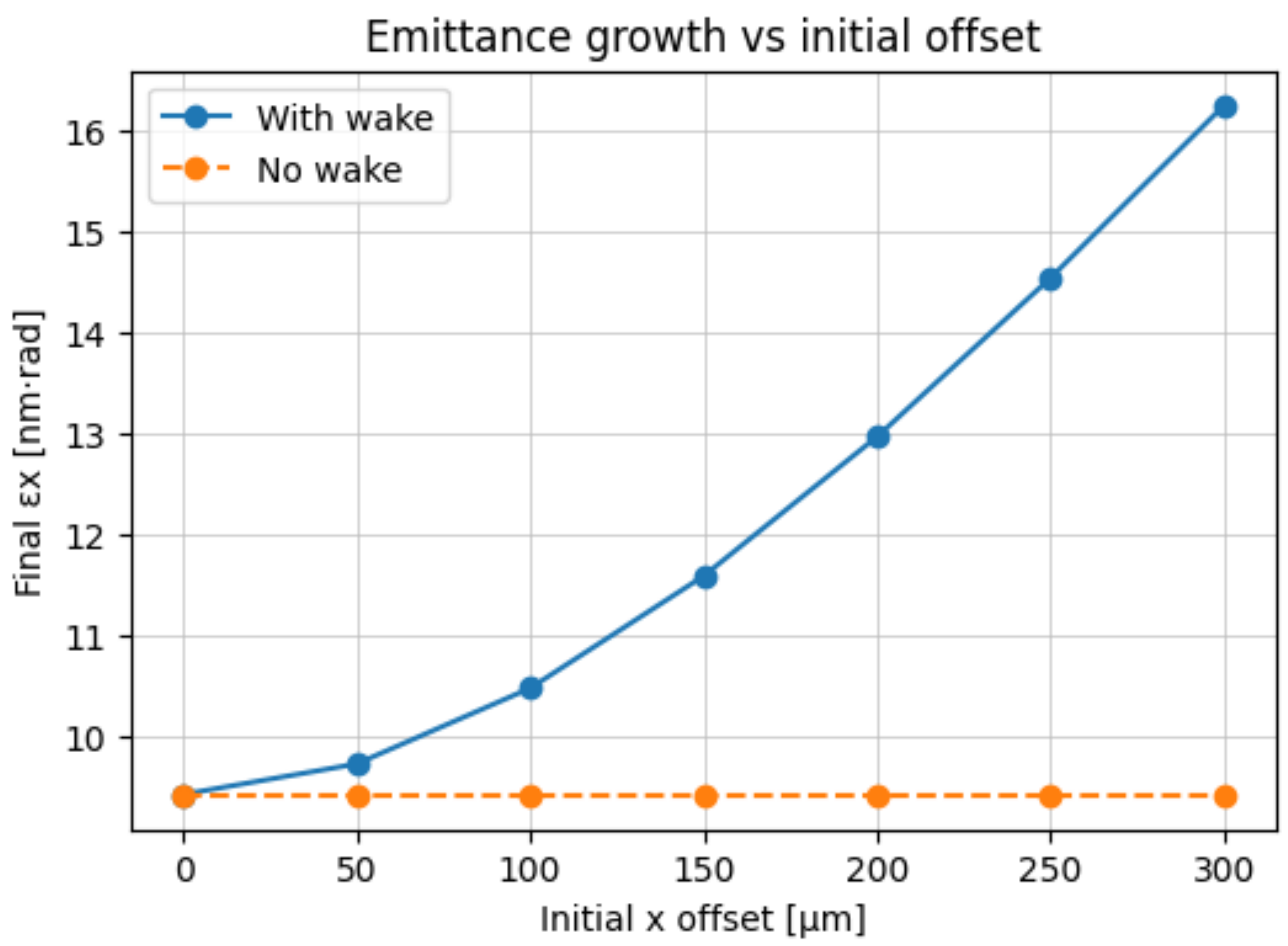


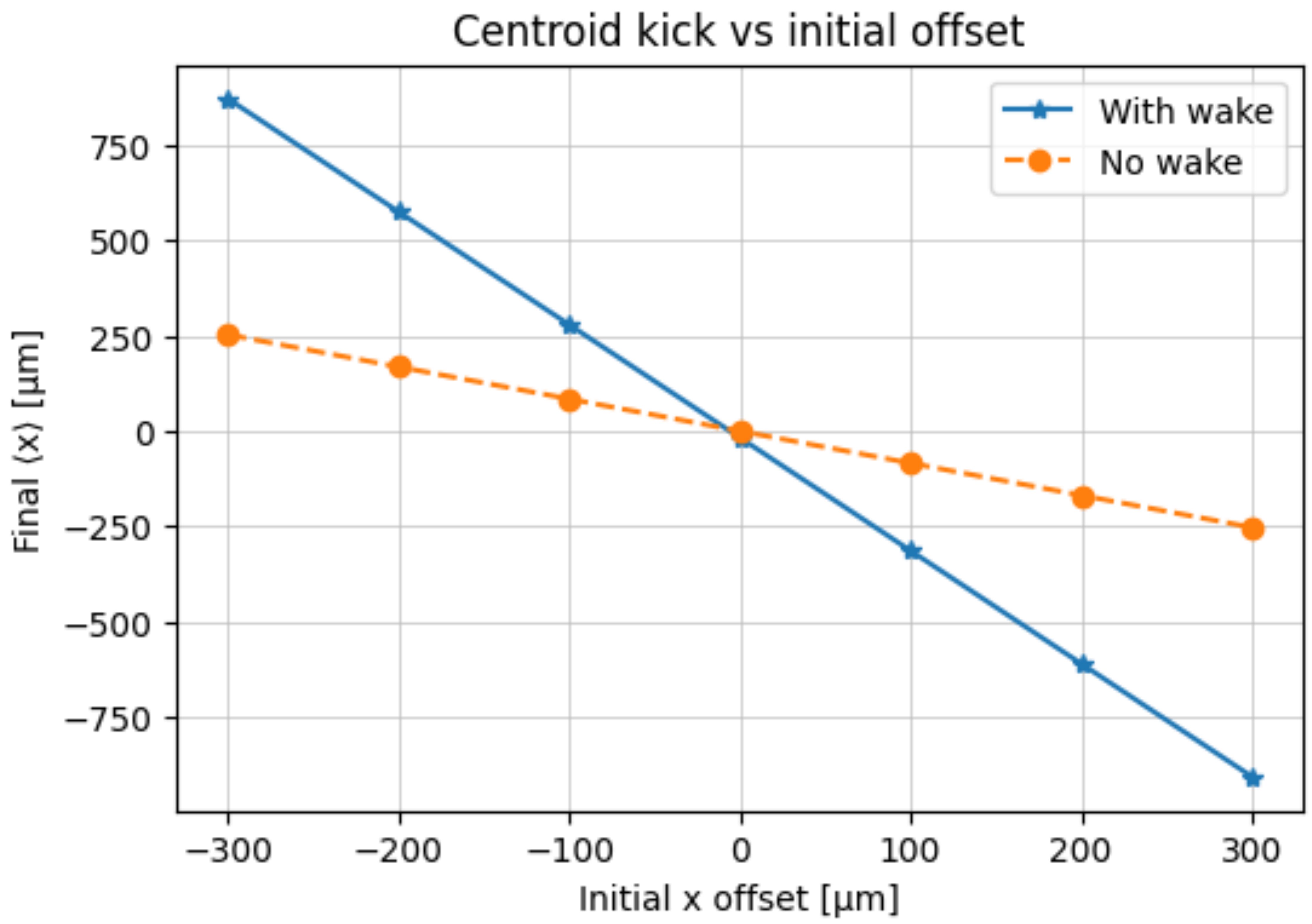
We do an offset in x. But wakefield is weak

Geometric emittance from second moments of the particle distribution:

Benchmark

```
x = x − np.mean(x)
xp = xp − np.mean(xp)
sig_x2  = np.mean(x*x)
sig_xp2 = np.mean(xp*xp)
sig_xxp = np.mean(x*xp)
return np.sqrt(max(sig_x2*sig_xp2 − sig_xxp**2, 0.0))
```



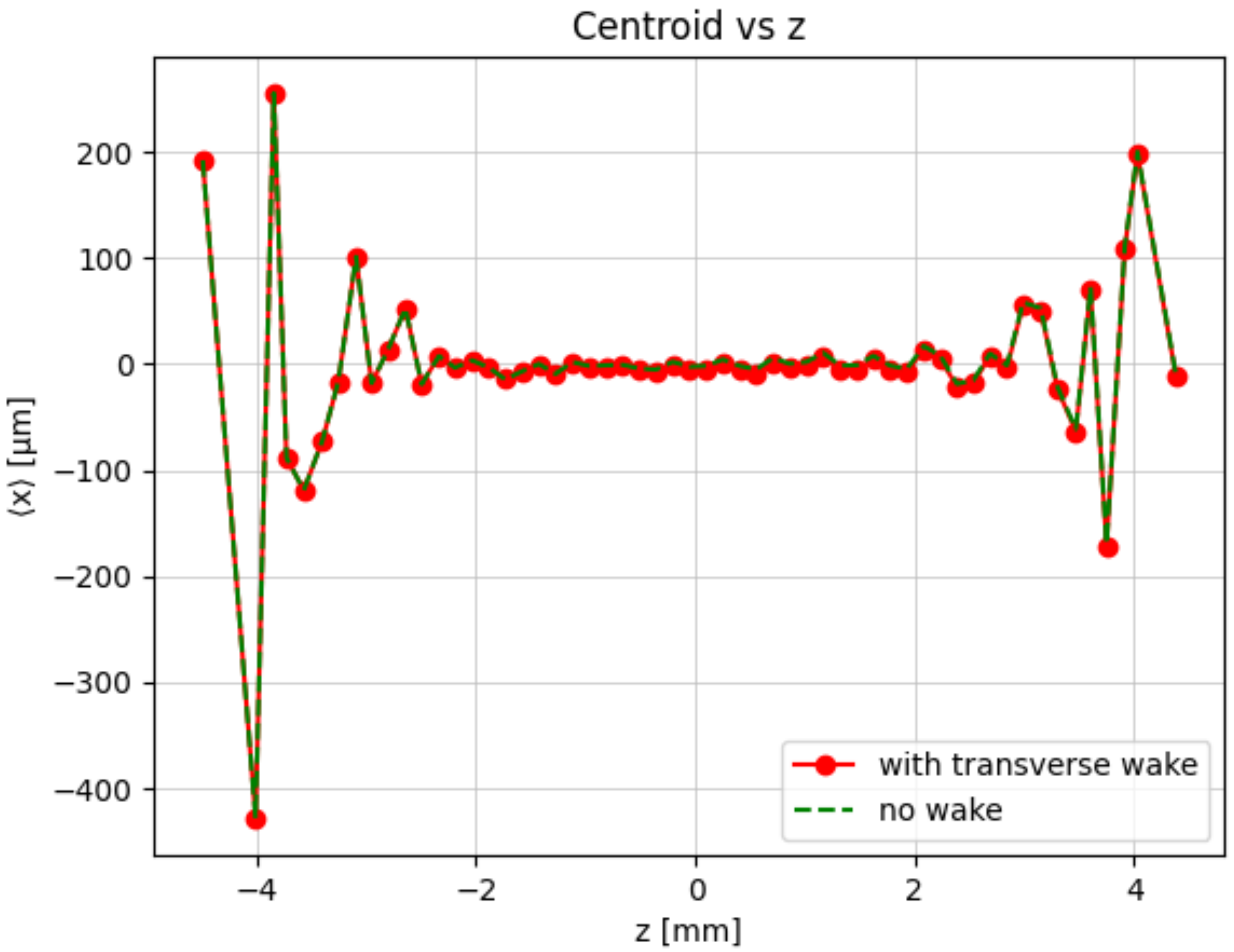


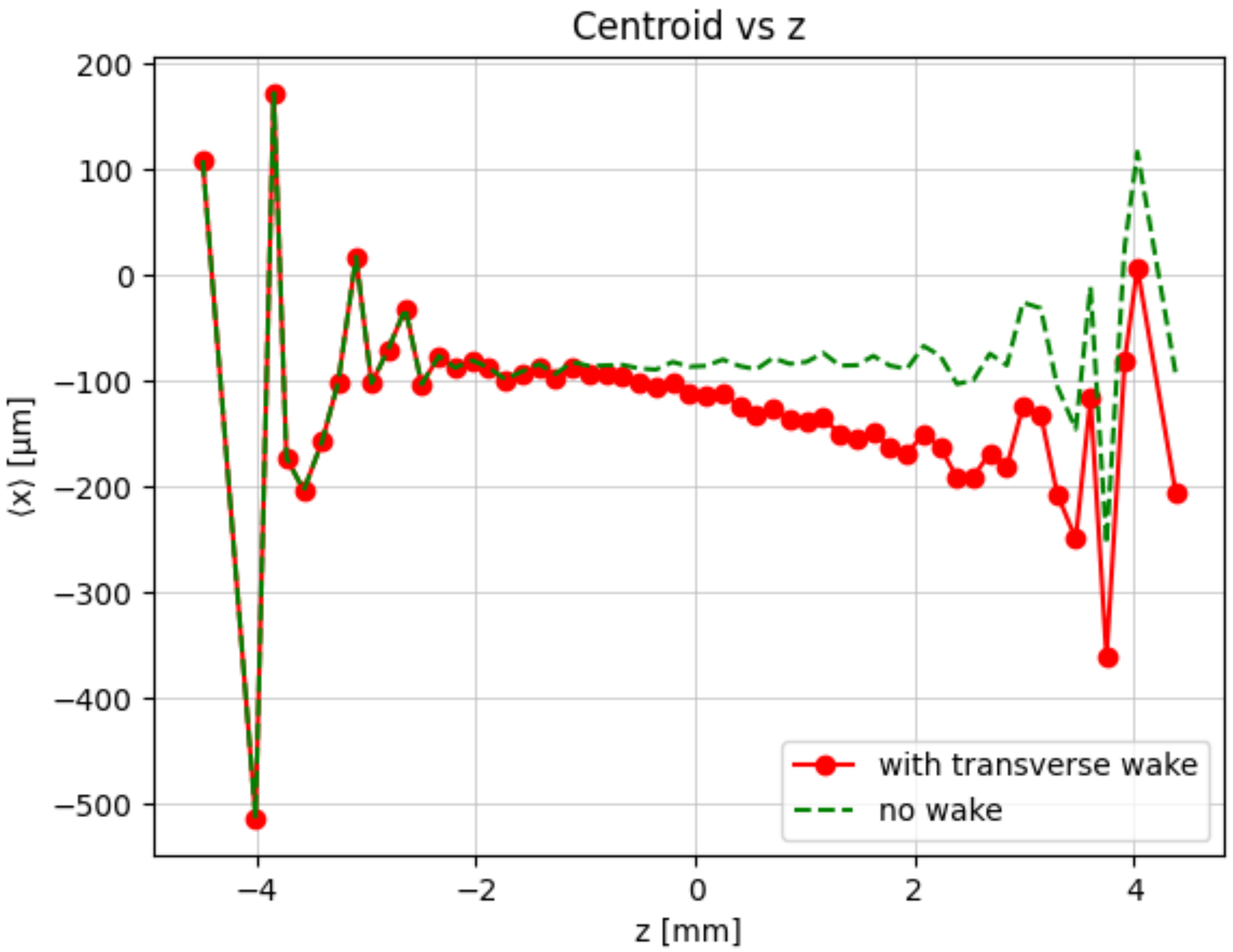
DESY.

Benchmark

NO offset

Weak offset



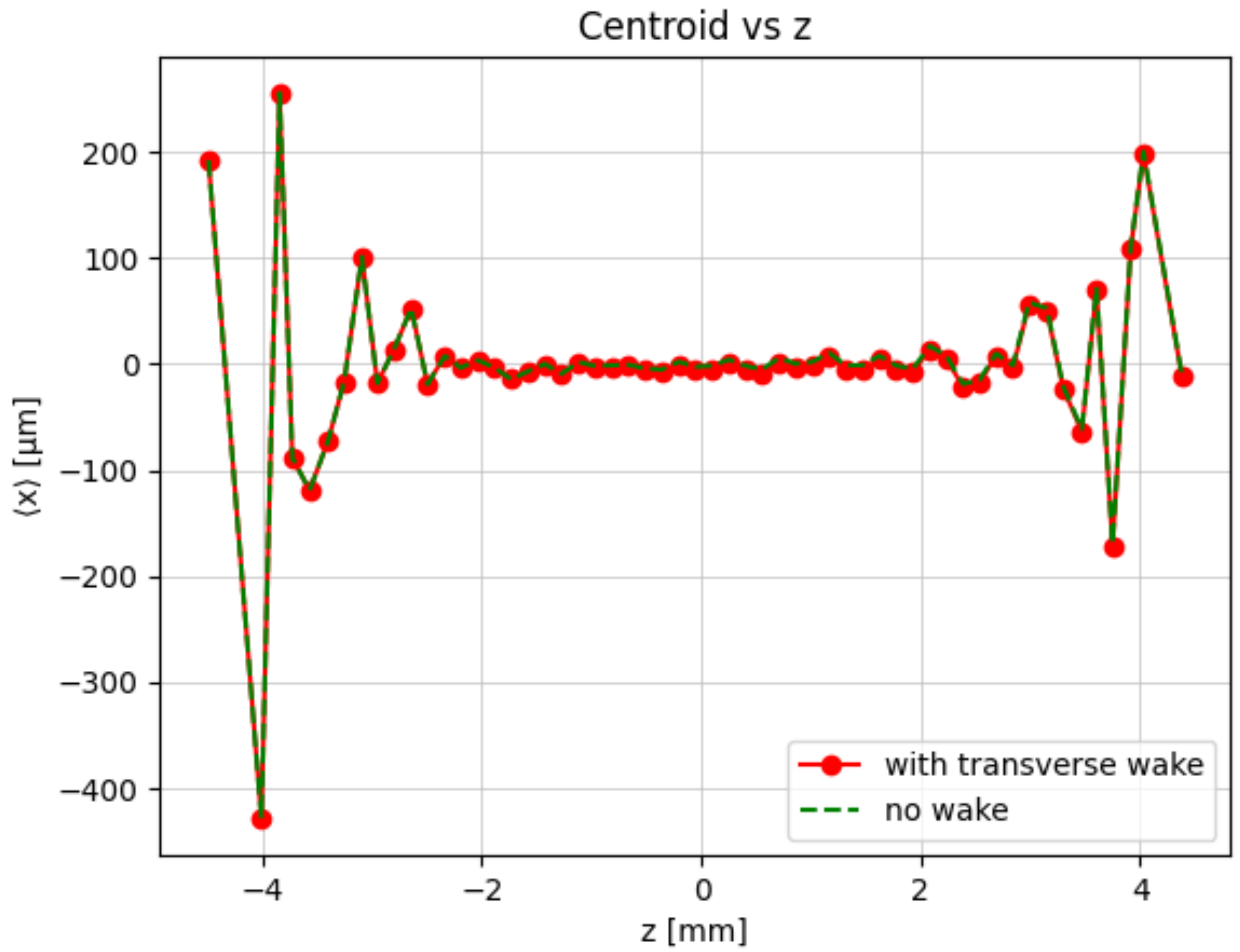


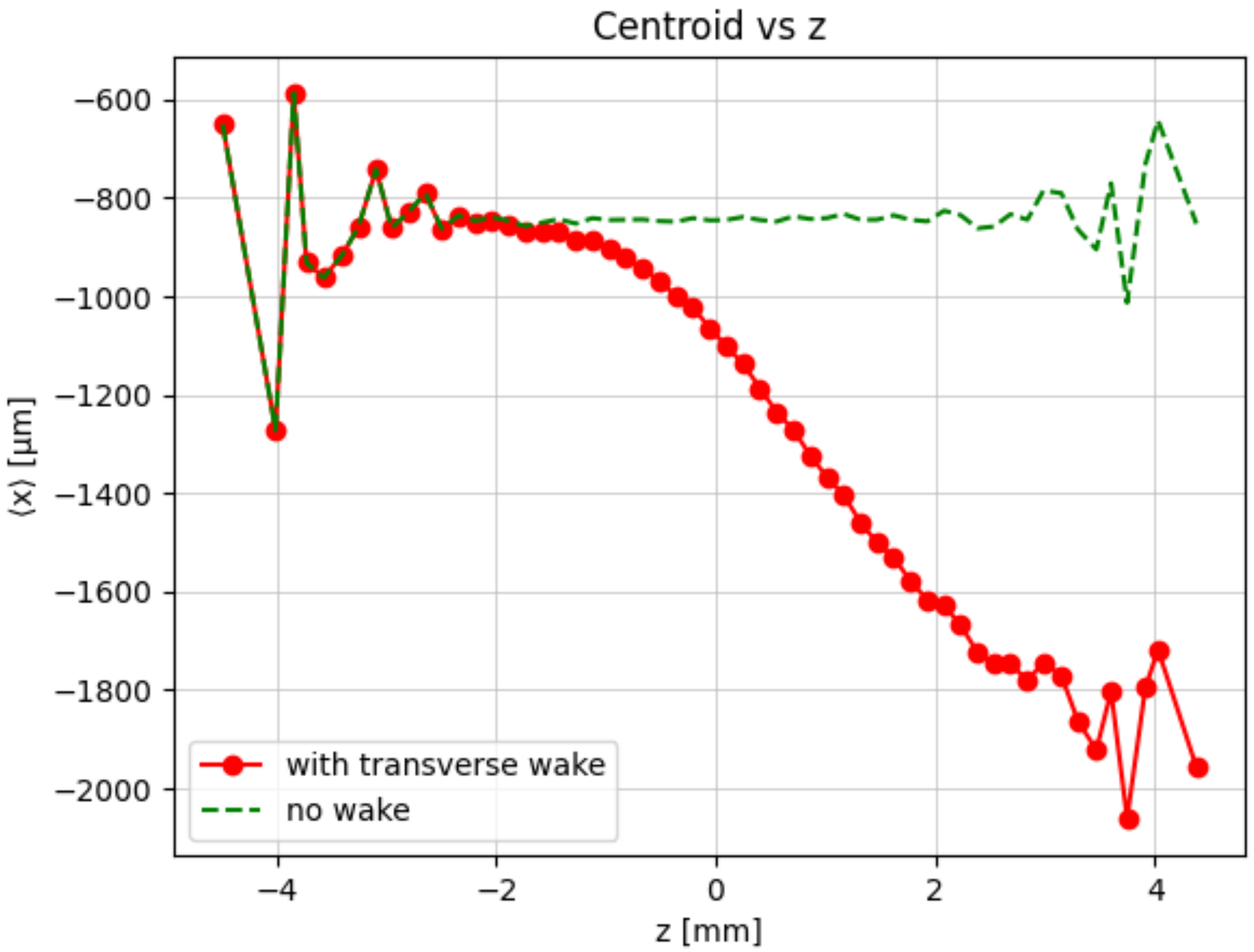
DESY.

Benchmark

NO offset

Strong offset

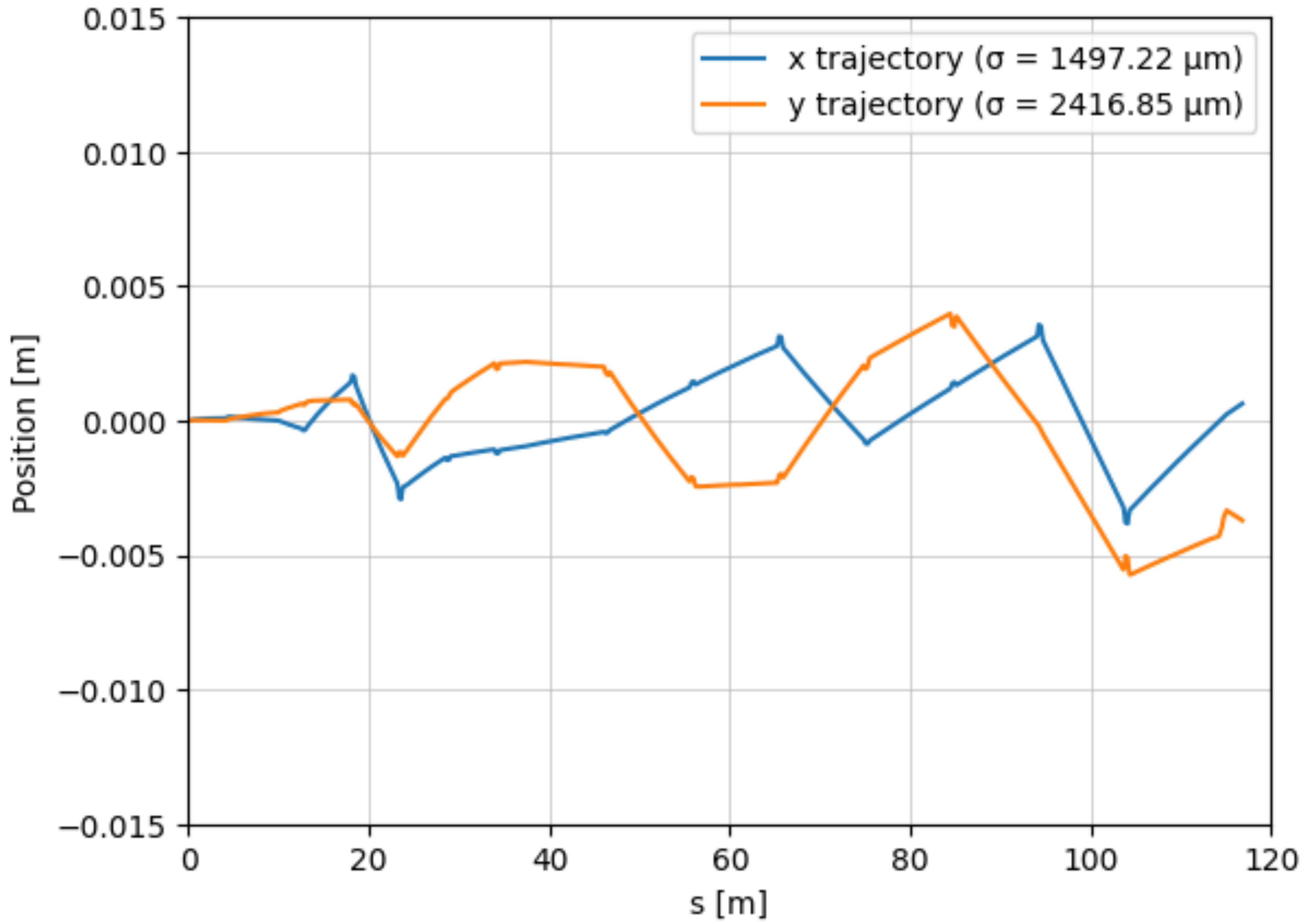




Orbit: LINAC sectA

For transverse wakefields we need misalignments

100 μm misalignment create this orbit (w/o wakefield:)

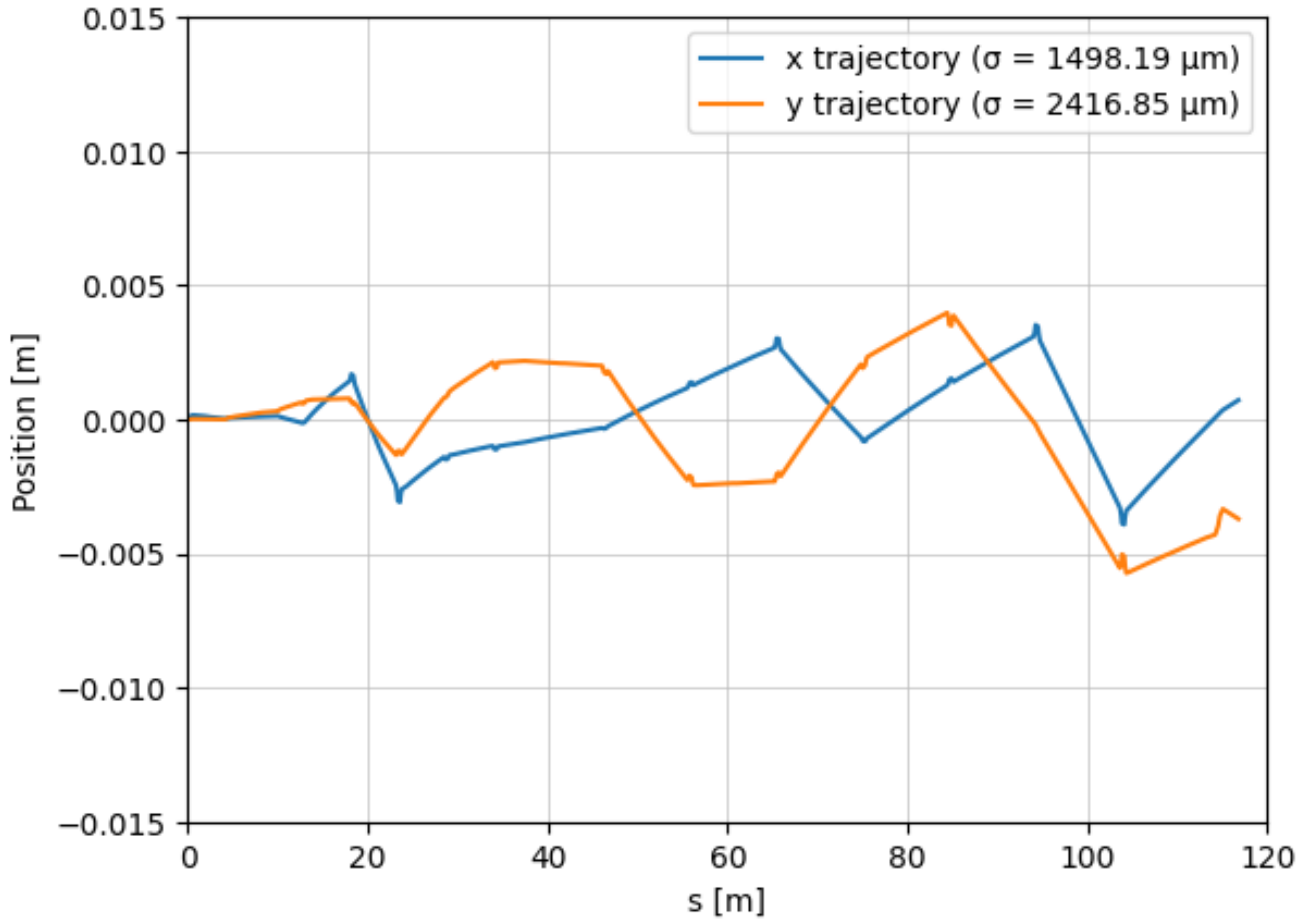


Orbit: LINAC sectA

For transverse wakefields we need misalignments

100 μm misalignment create this orbit (w/o wakefield:)

+100 µm initial offset

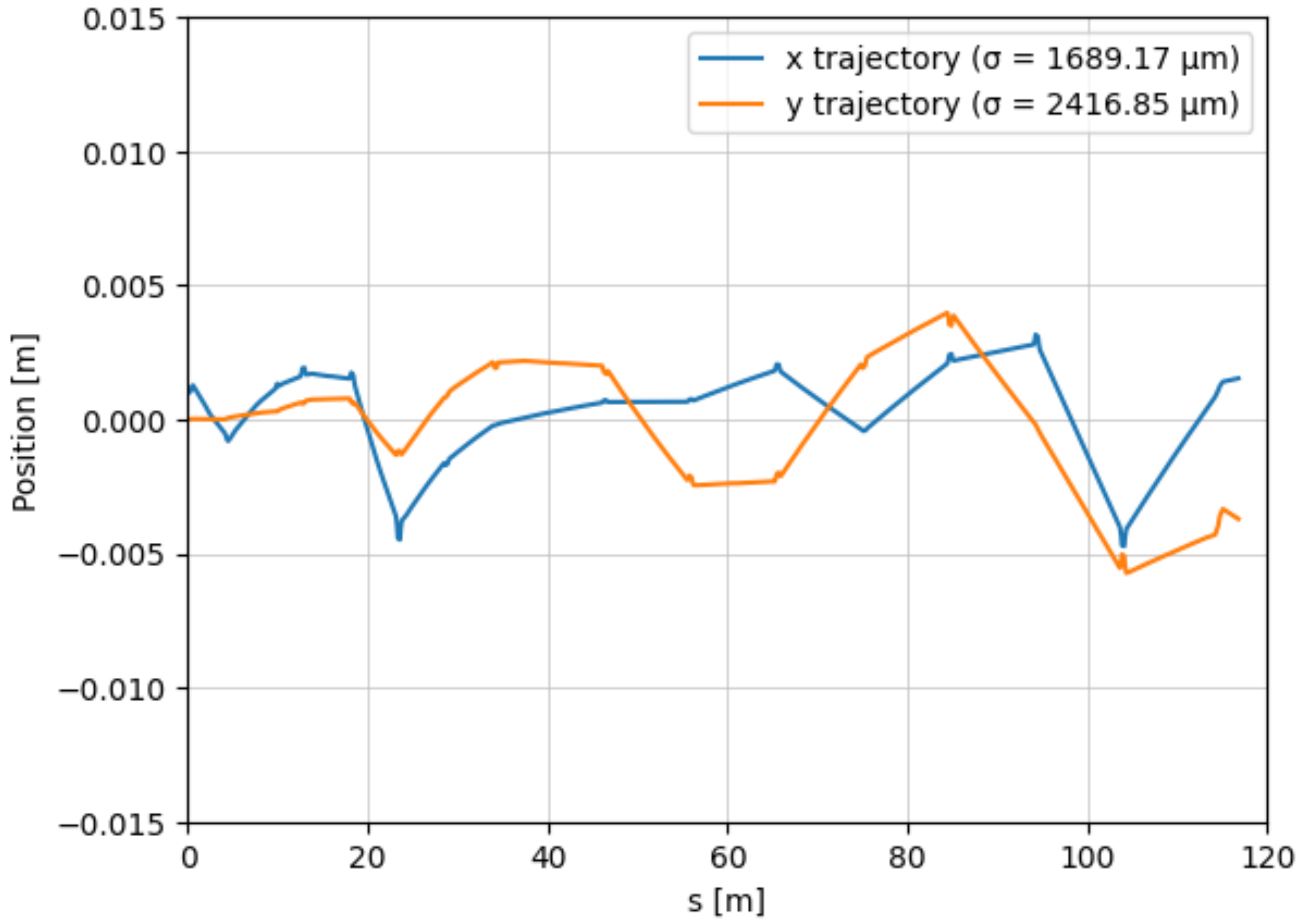


Orbit: LINAC sectA

For transverse wakefields we need misalignments

100 μm misalignment create this orbit (w/o wakefield:)

+1000 µm initial offset

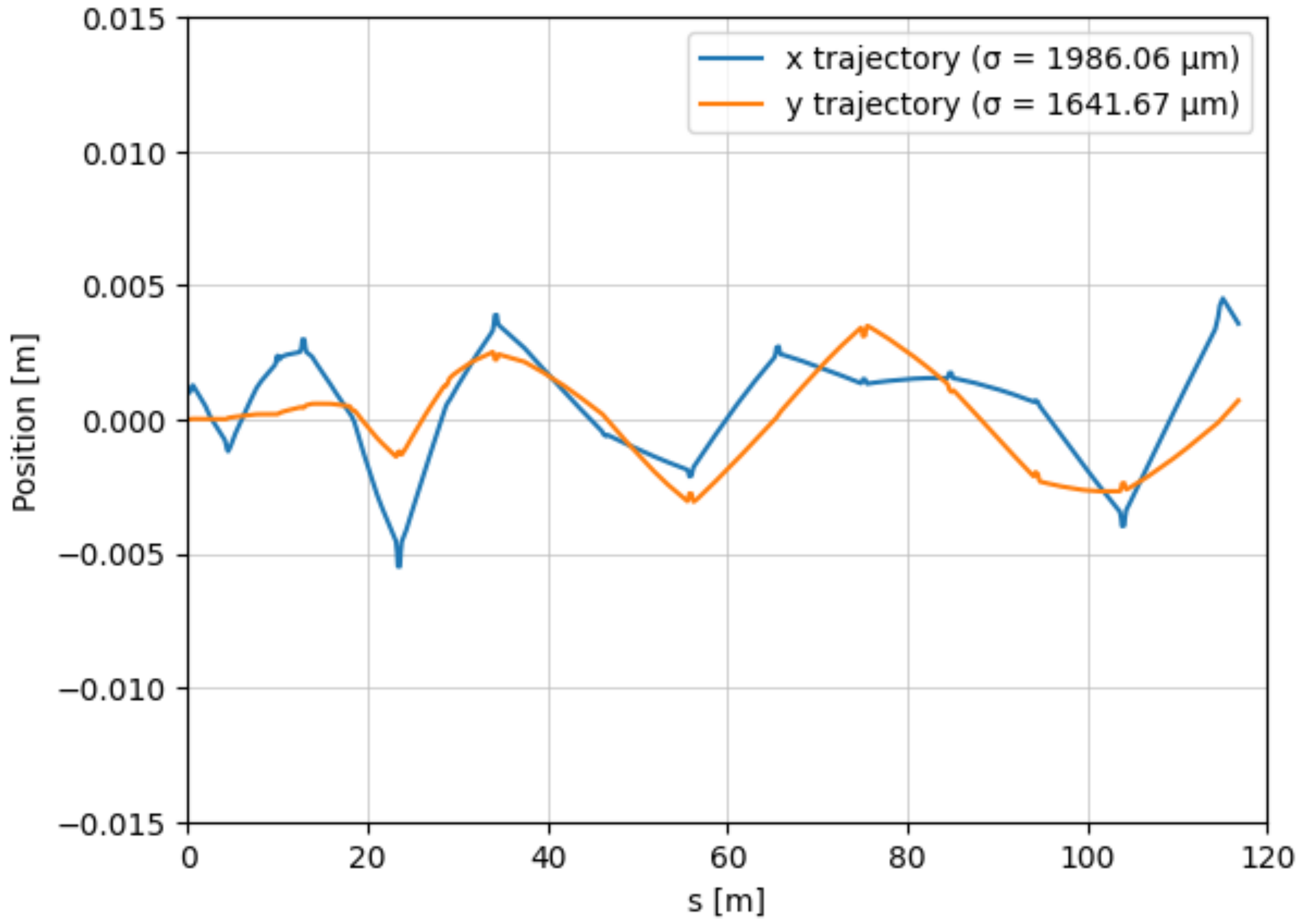


Orbit: LINAC sectA

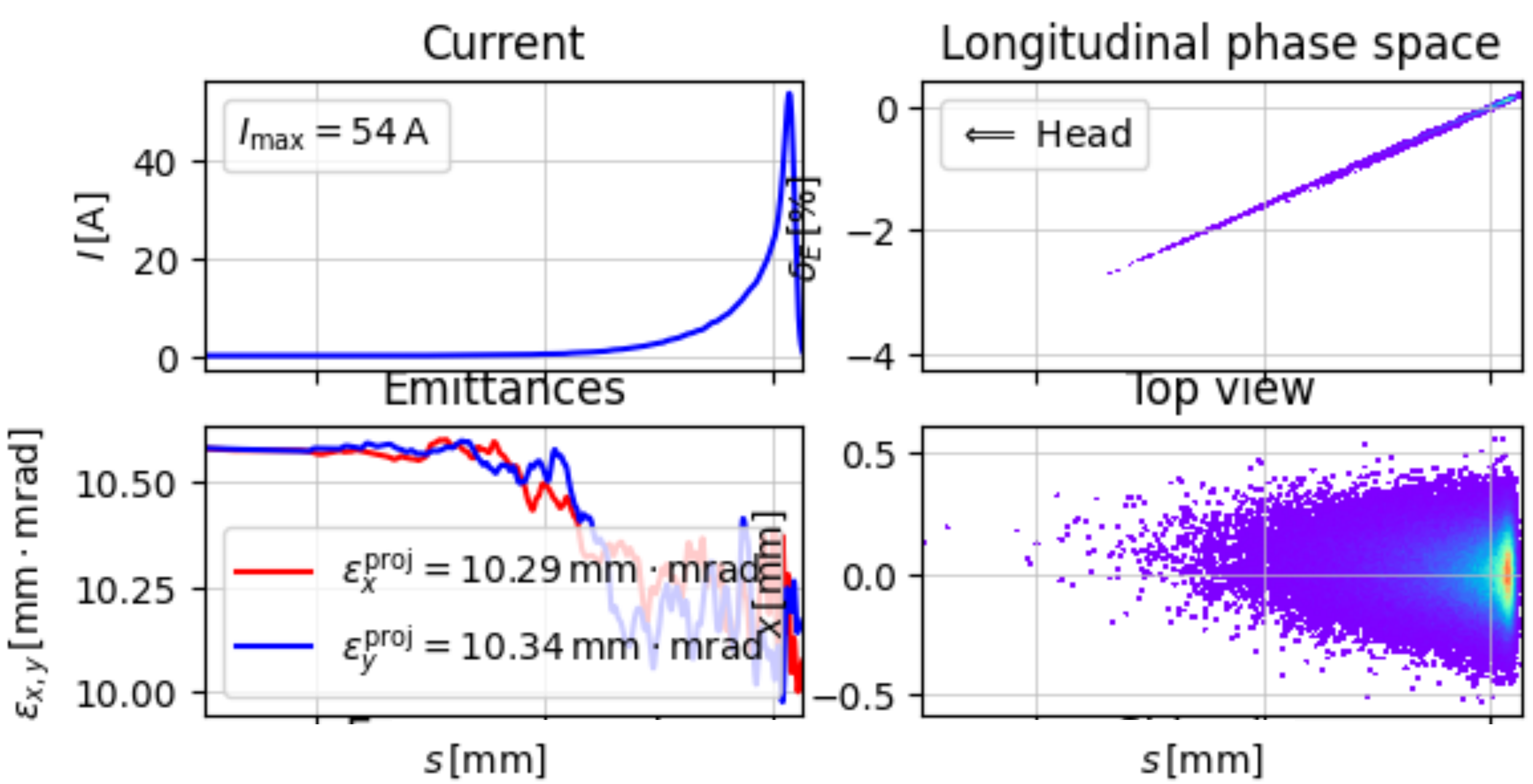
For transverse wakefields we need misalignments

100 μm misalignment create this orbit (w/o wakefield:)

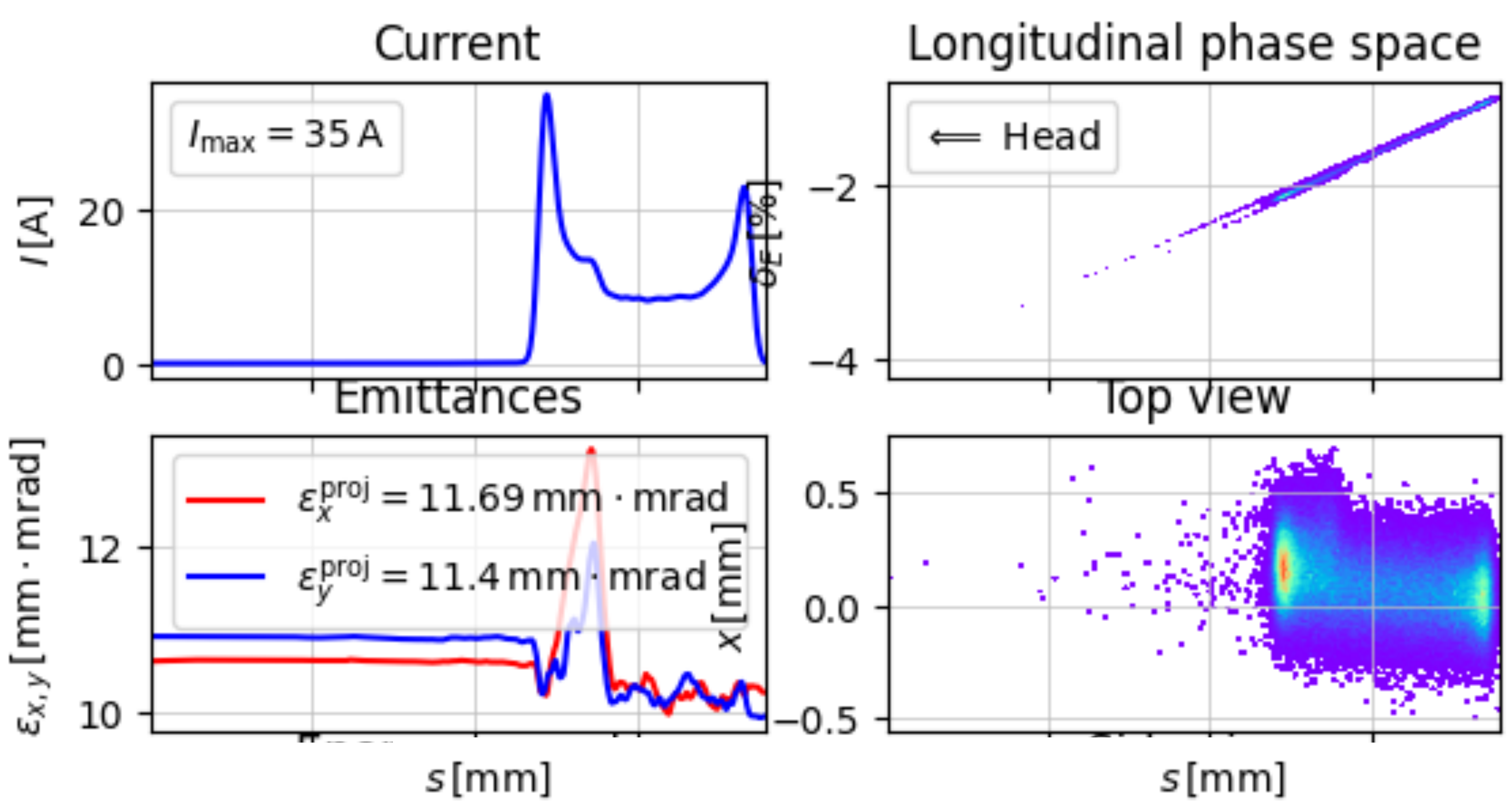
+1000 μm initial offset+Wake



No wakefields

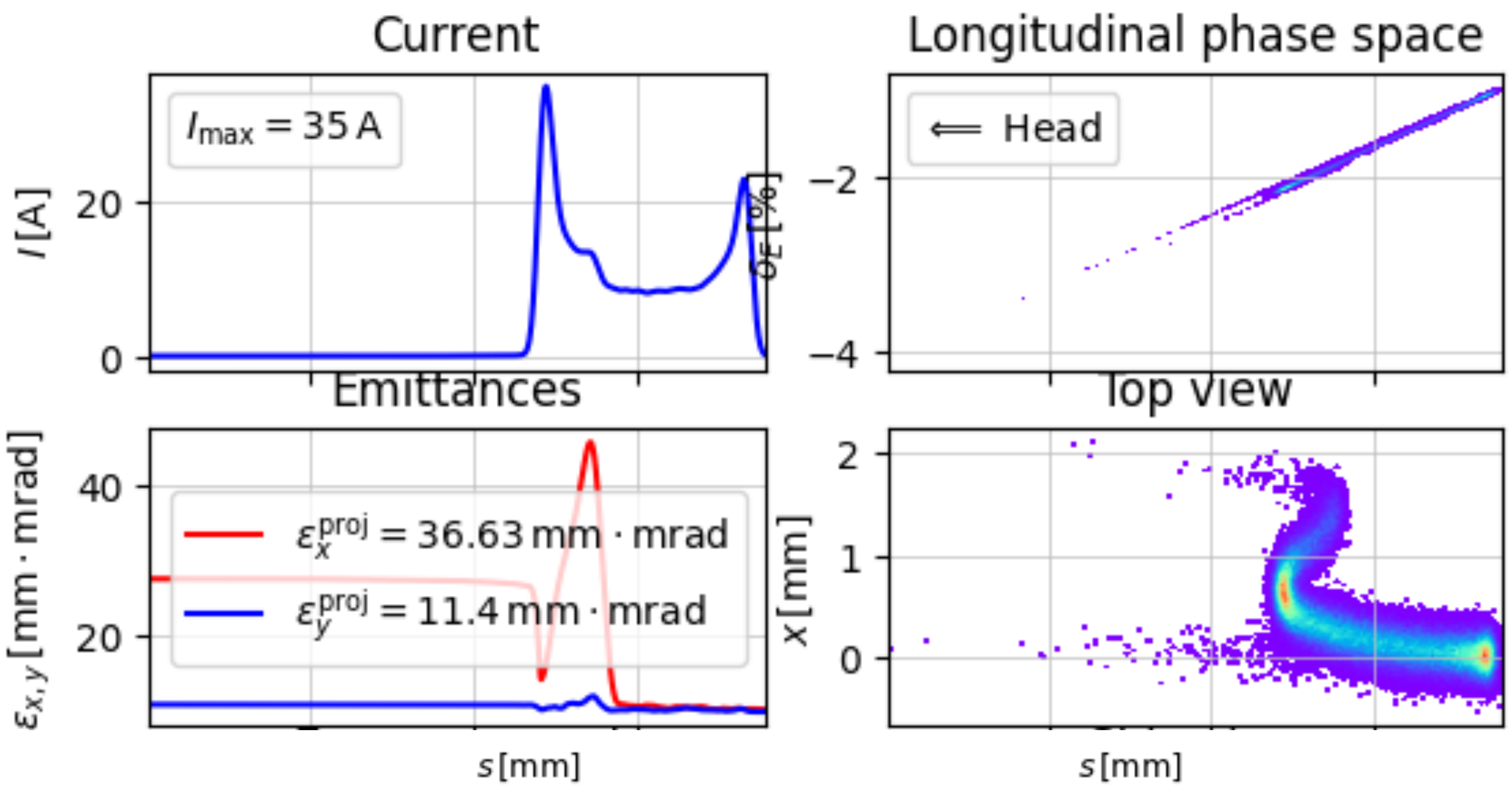


Wakefields- NO transverse offset



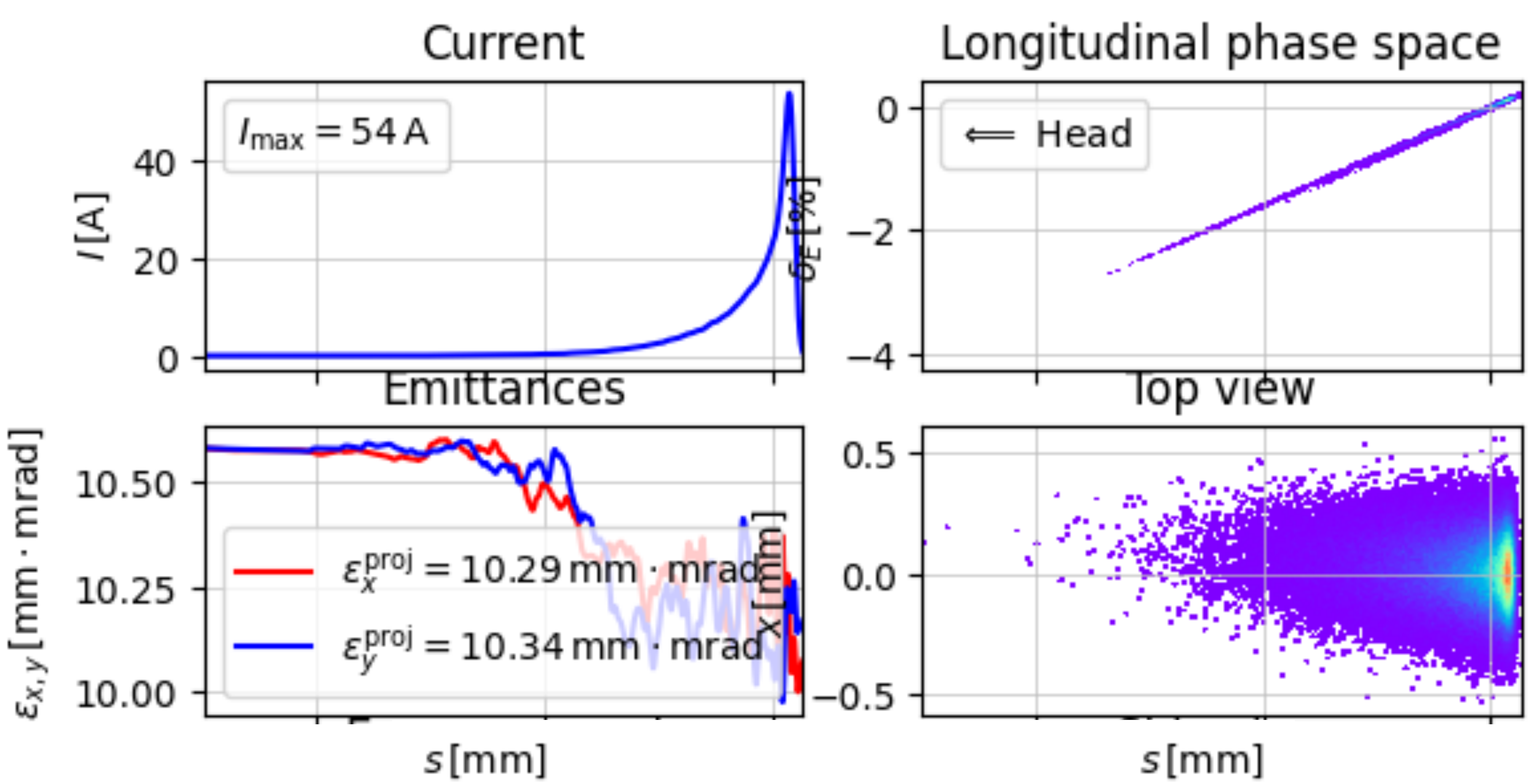
*MAKE MOVIE

Wakefields- initial transverse offset

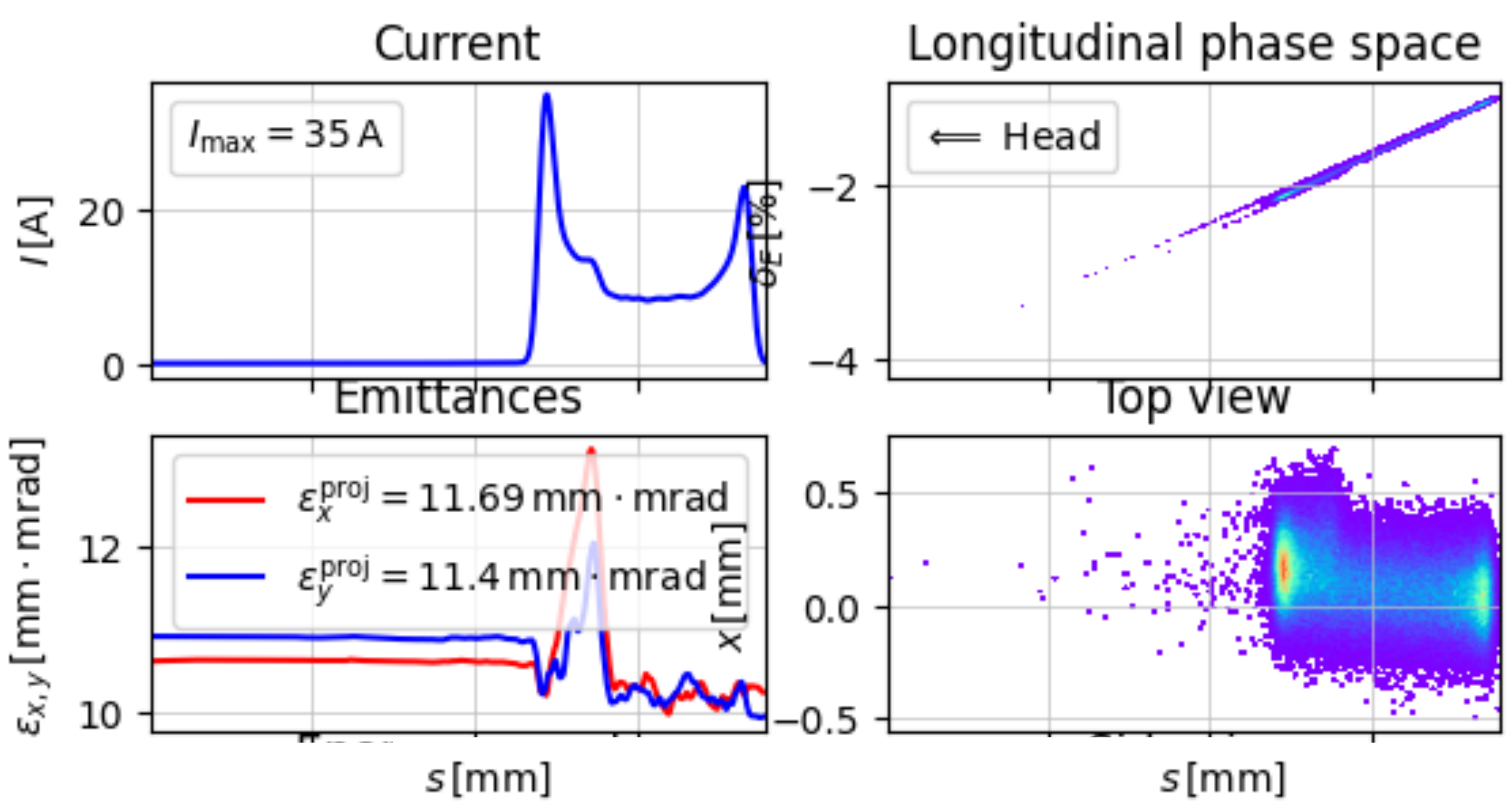


+50 μm offset

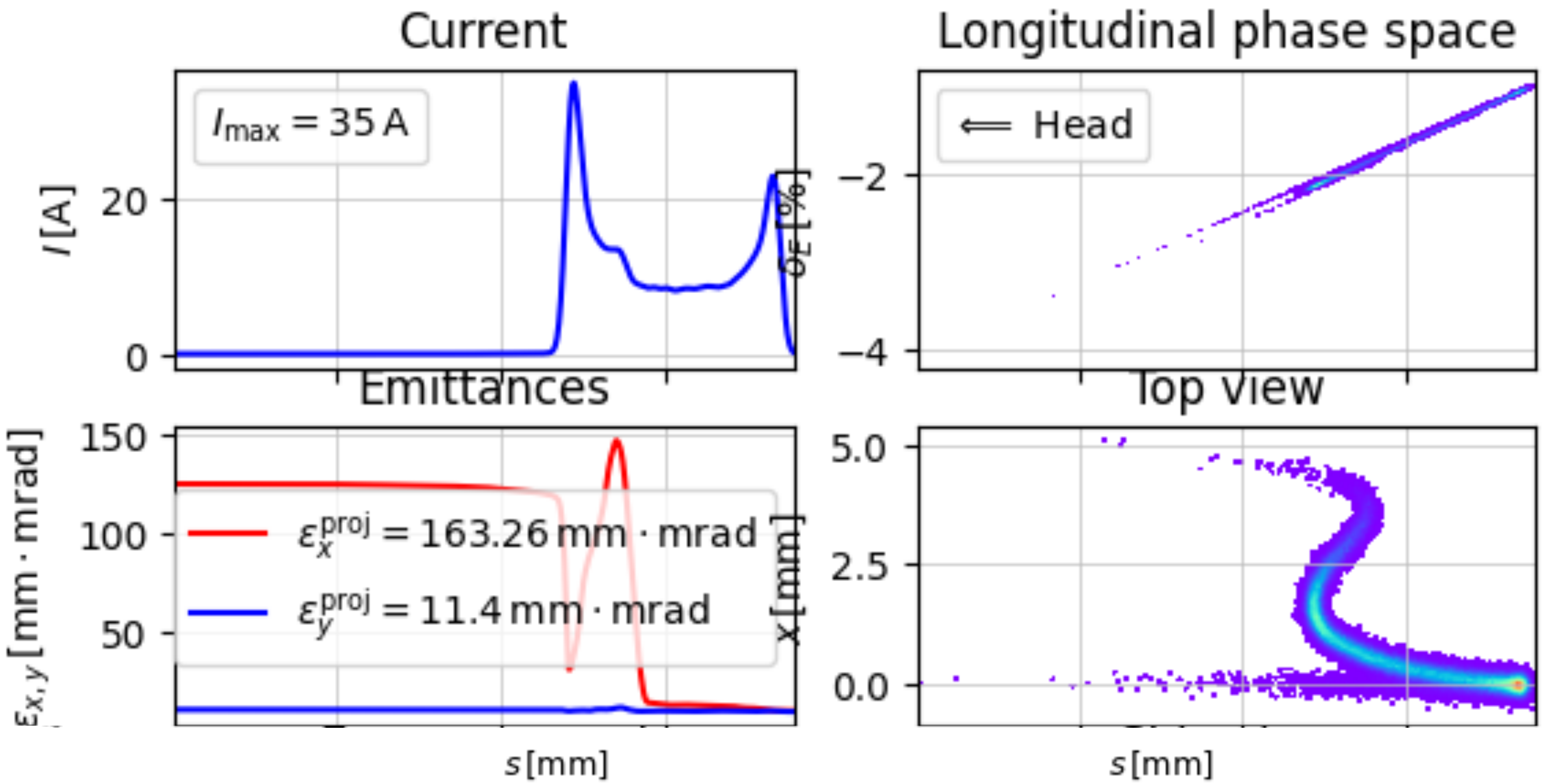
No wakefields



Wakefields- NO transverse offset

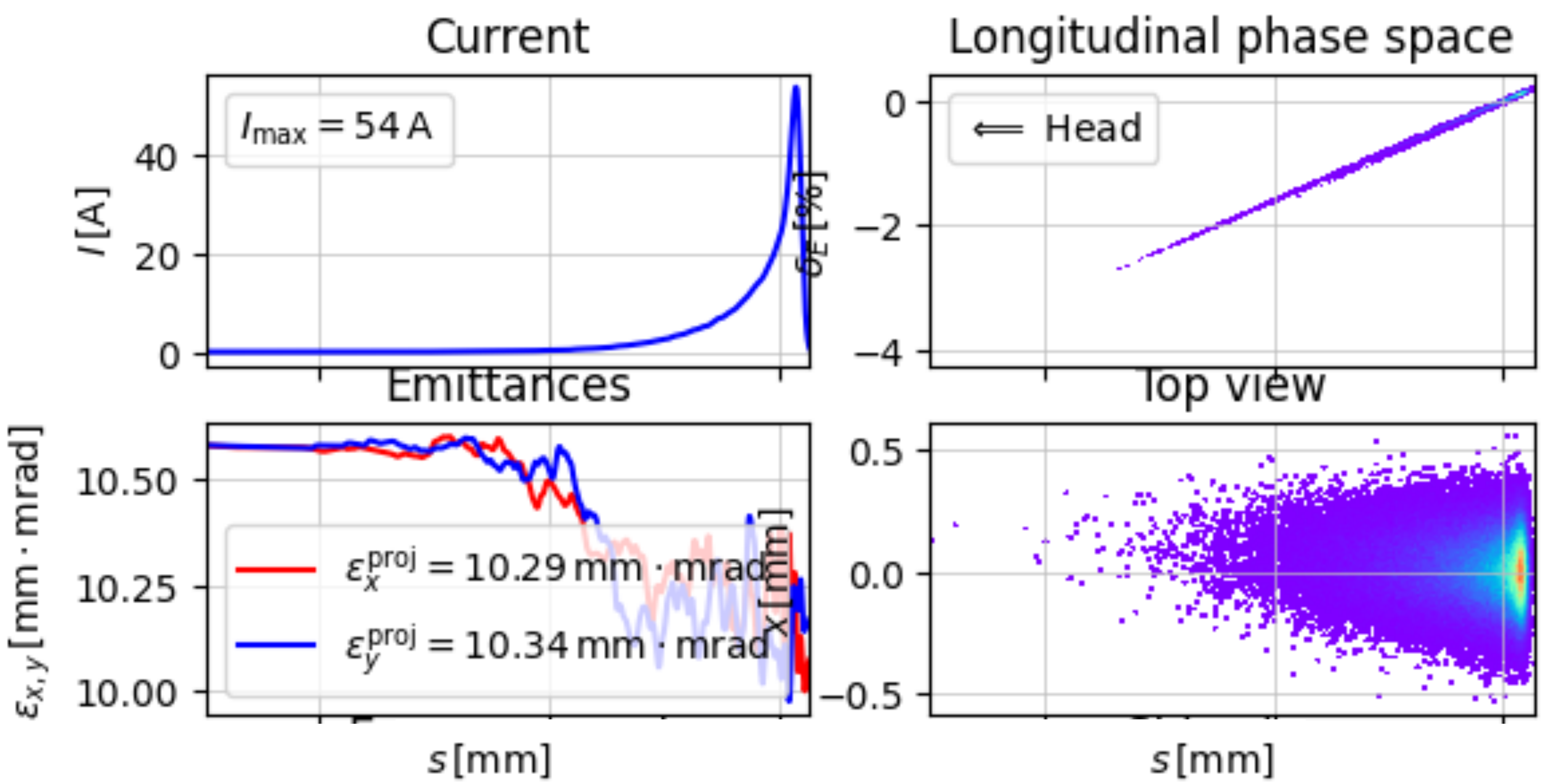


Wakefields- initial transverse offset

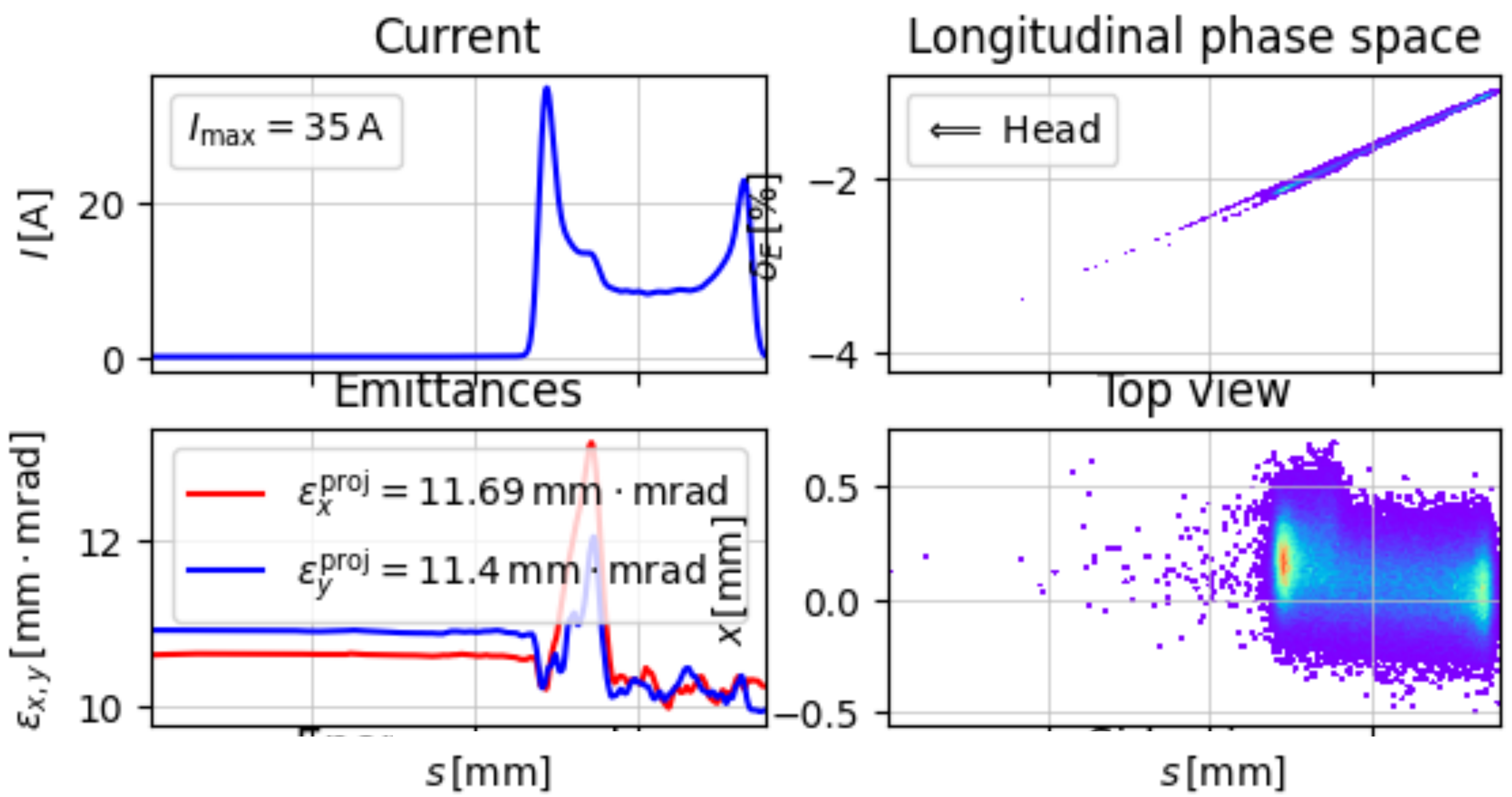


+150 μm offset

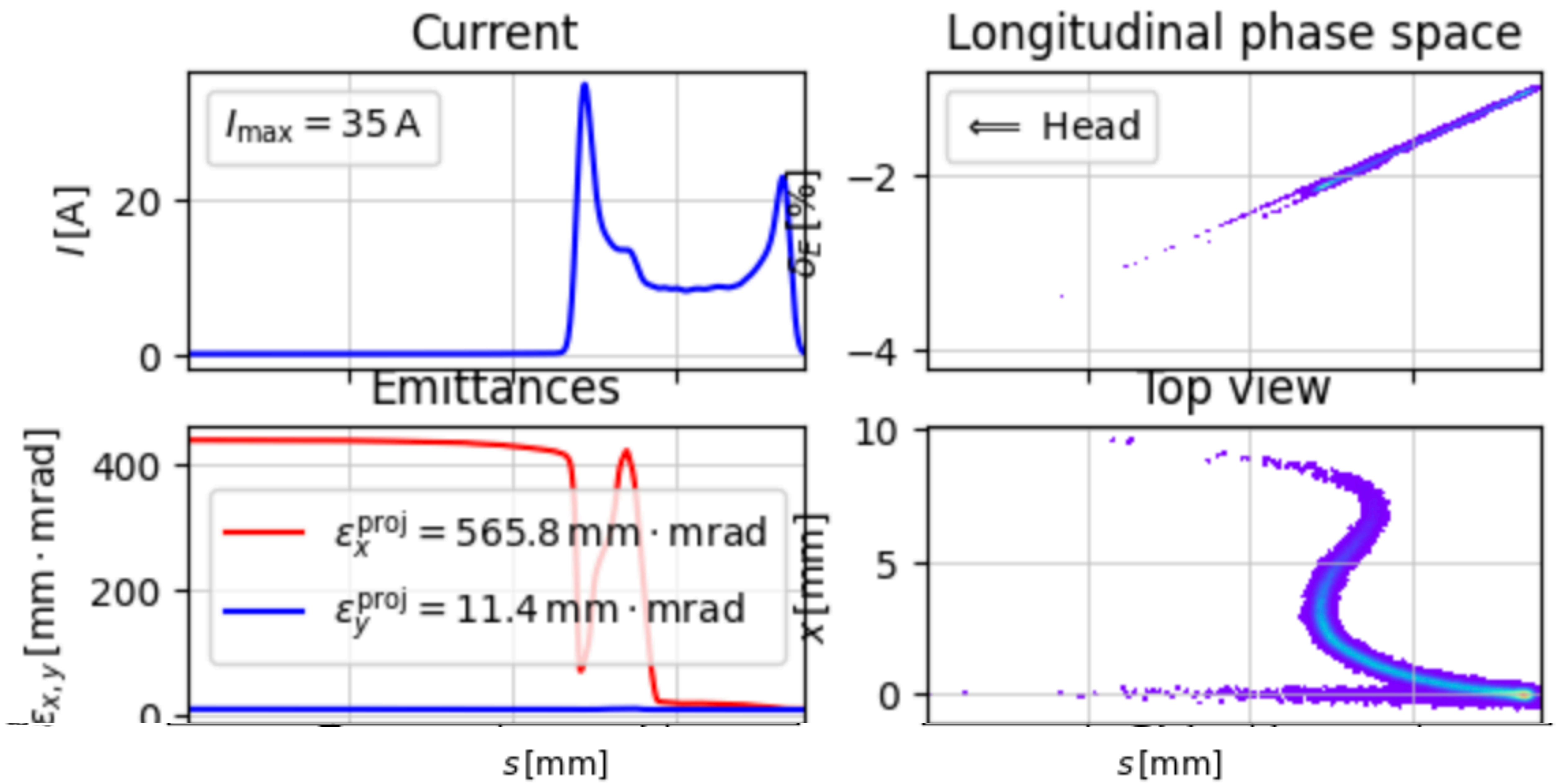
No wakefields



Wakefields- NO transverse offset



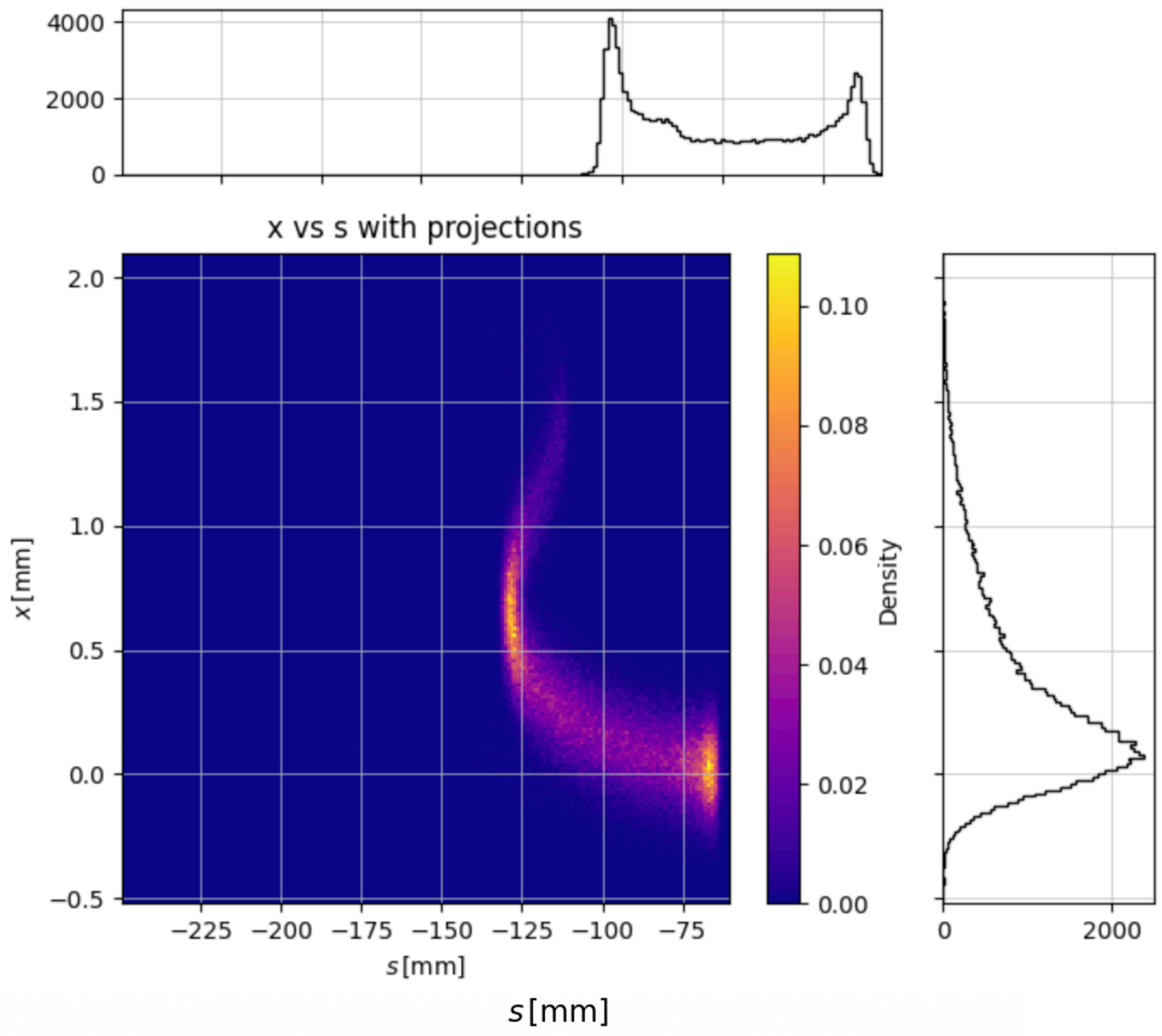
Wakefields- initial transverse offset

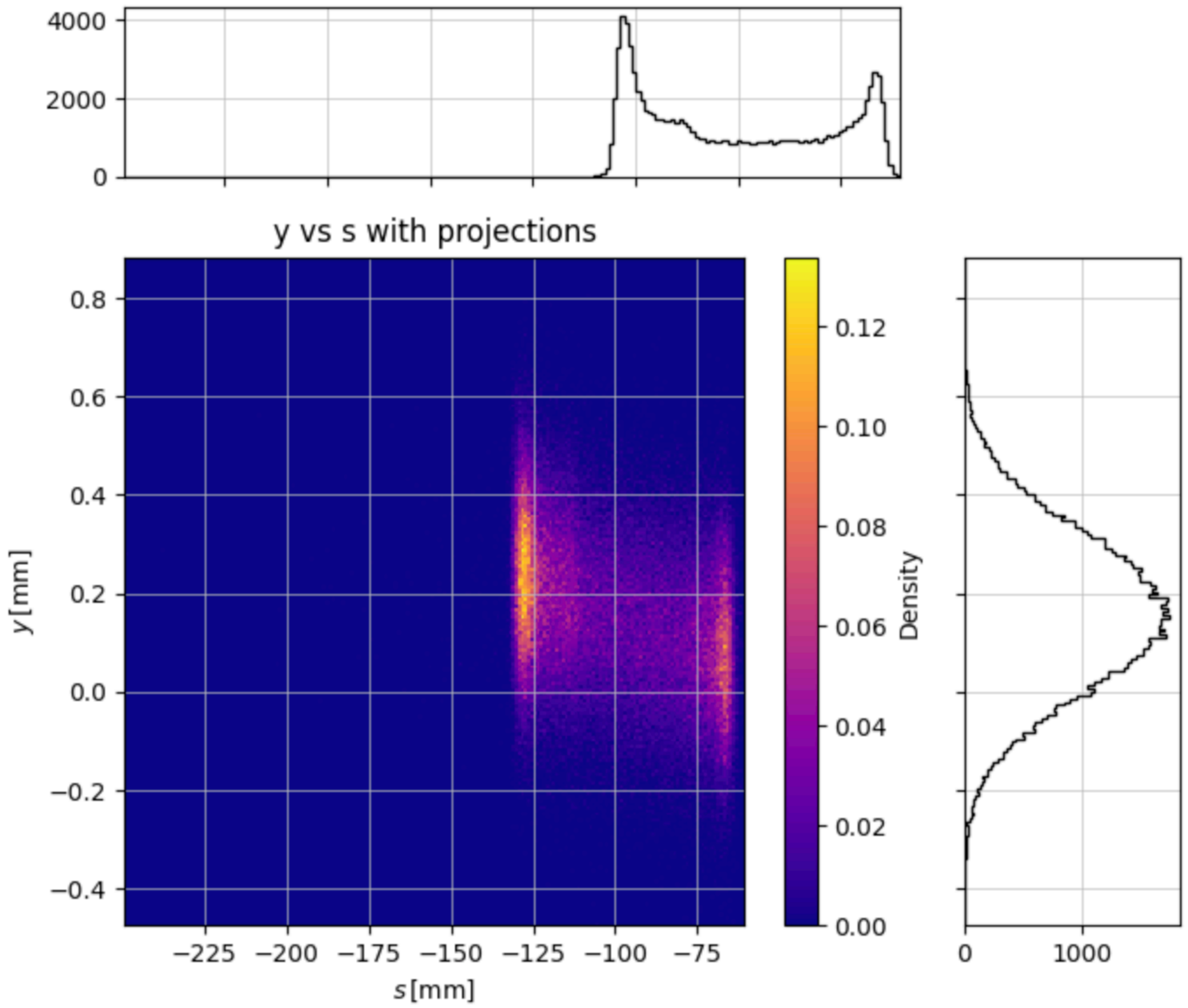


+300 μm offset

CASE: +50 μm offset

So by EYE we can see 2 peak here but projection doesn't show, we need further studies with dispersion





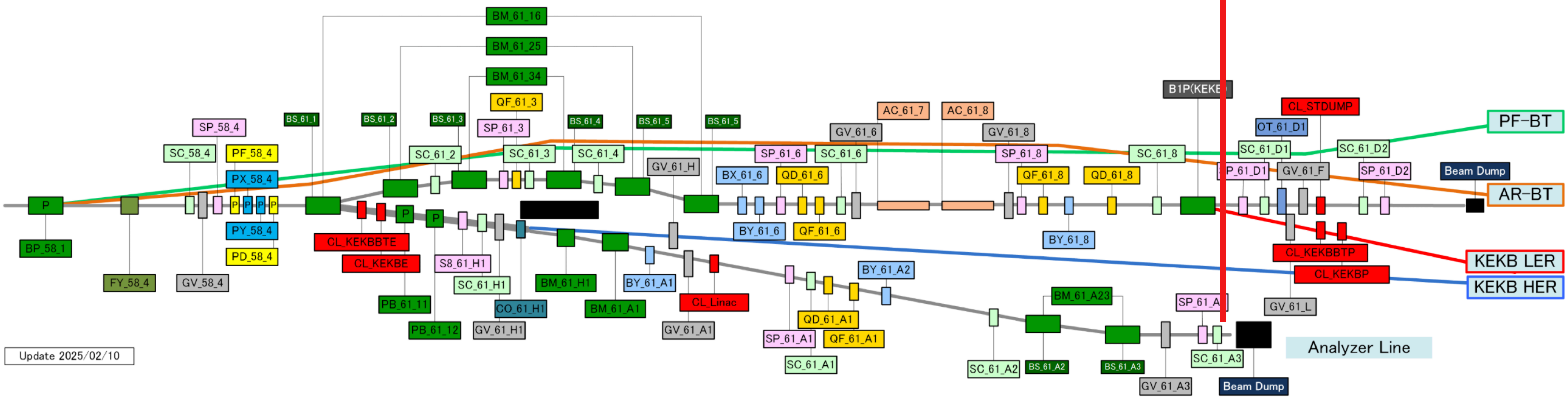
SuperKEKB injection meeting

- **Simulation of double-peak longitudinal structure and tracking trough the dump line**

Dump Line Beam Study

SC_61_A3

Linac SY3-East

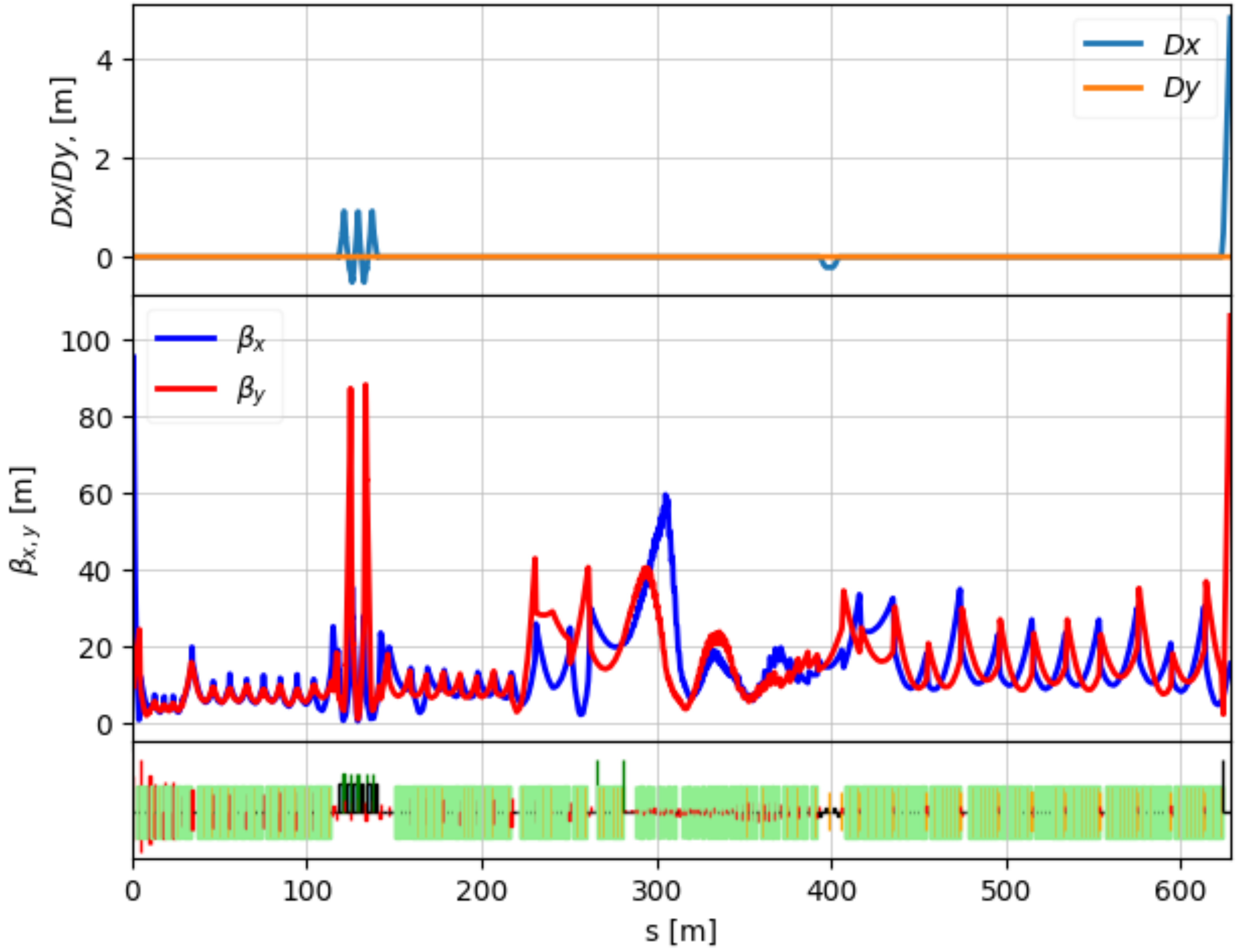


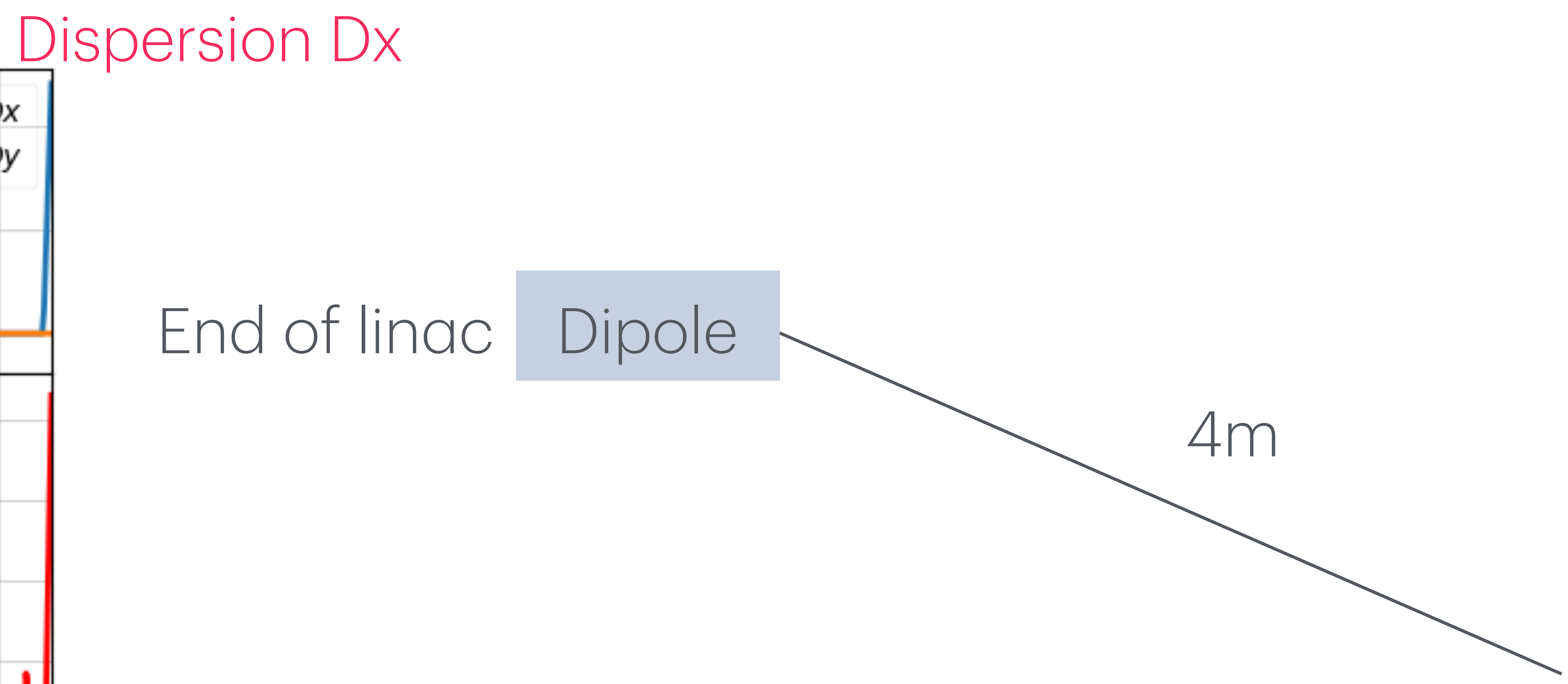
-does some SAD file has DUMP line?

WE DONT HAVE THIS BRANCH IN SAD FILE: WE WILL DO END OF LINAC

DESY.

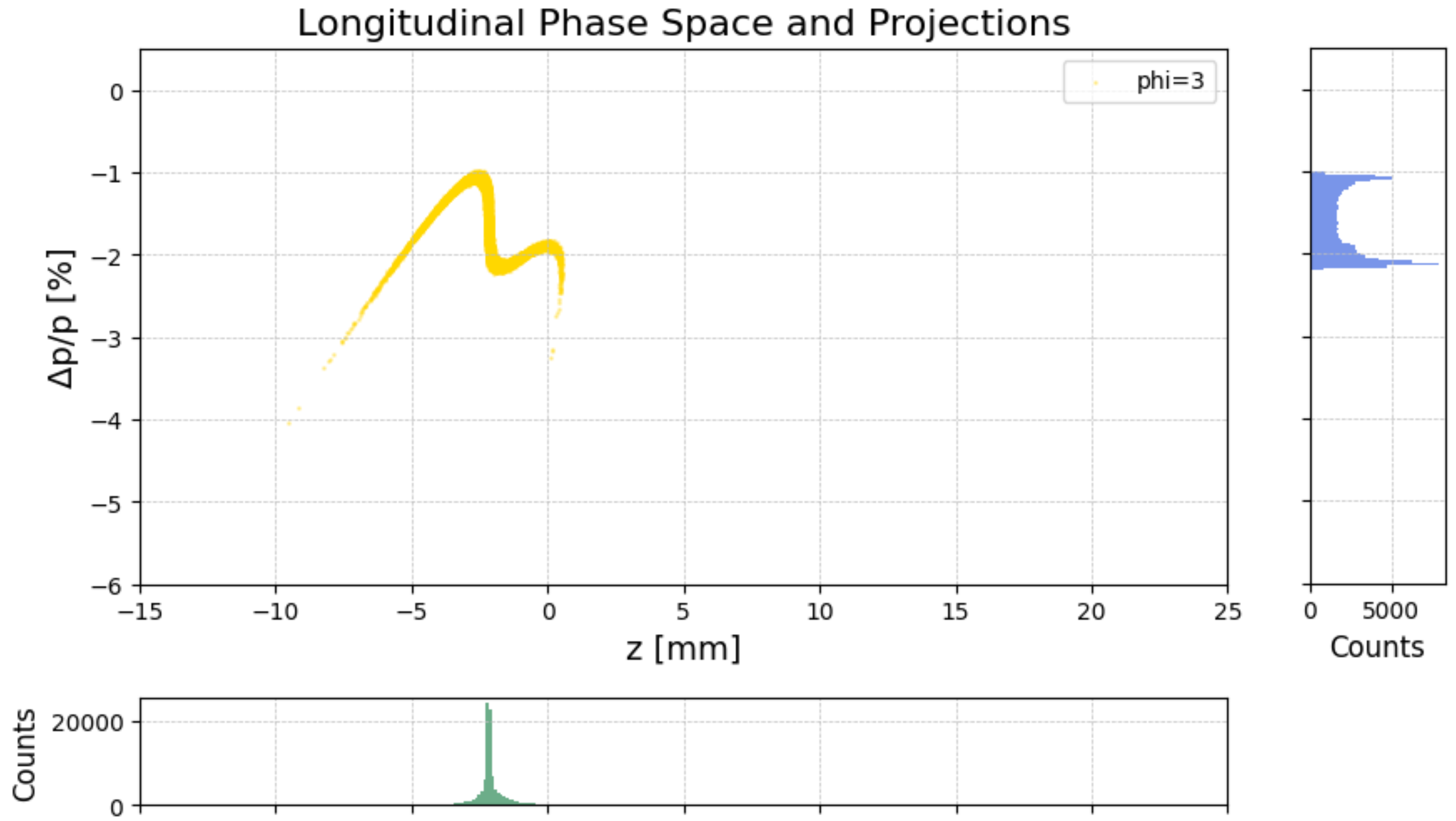
“Recreating” DUMP line

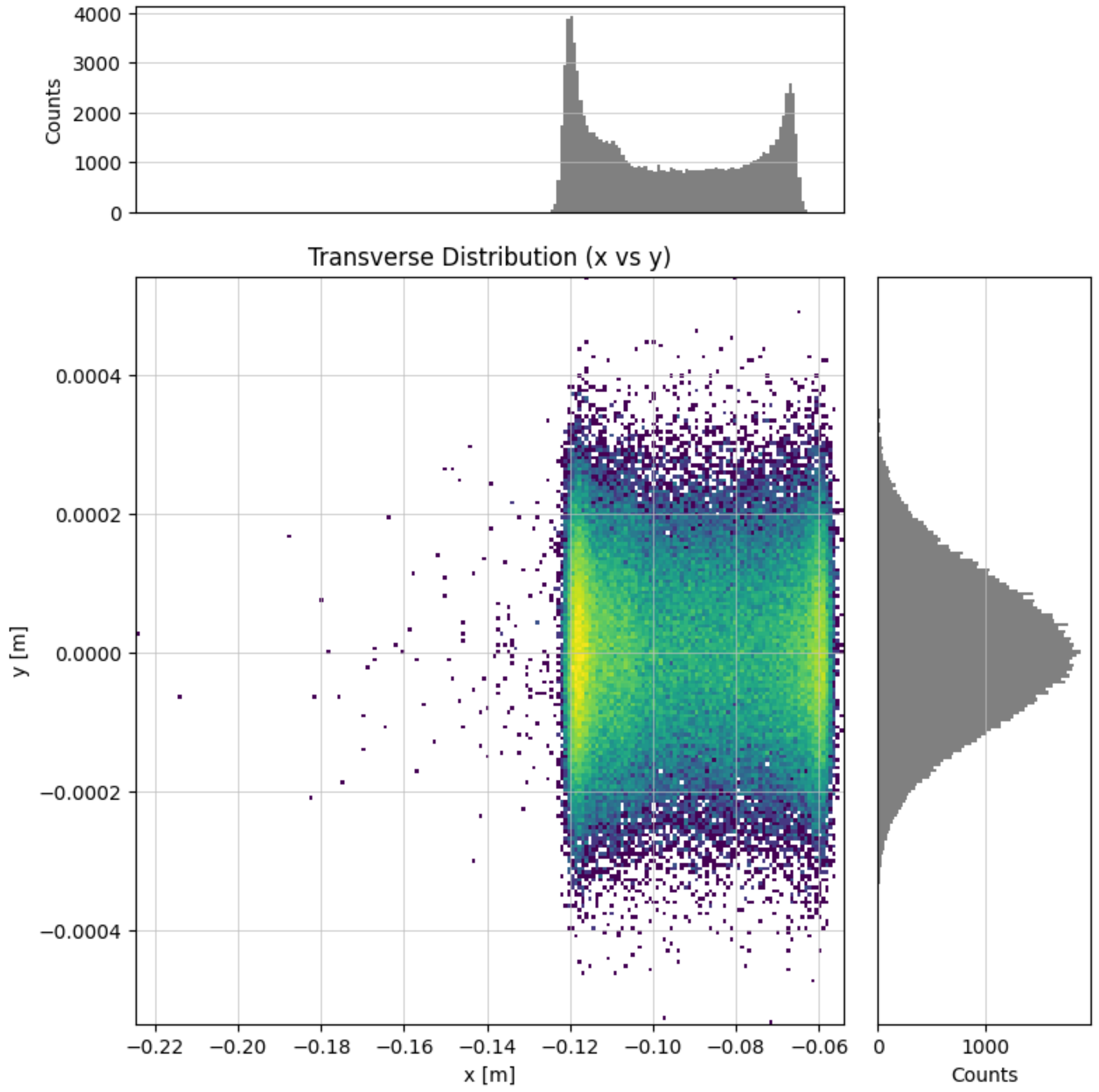




"Recreating" DUMP line

Phi=3

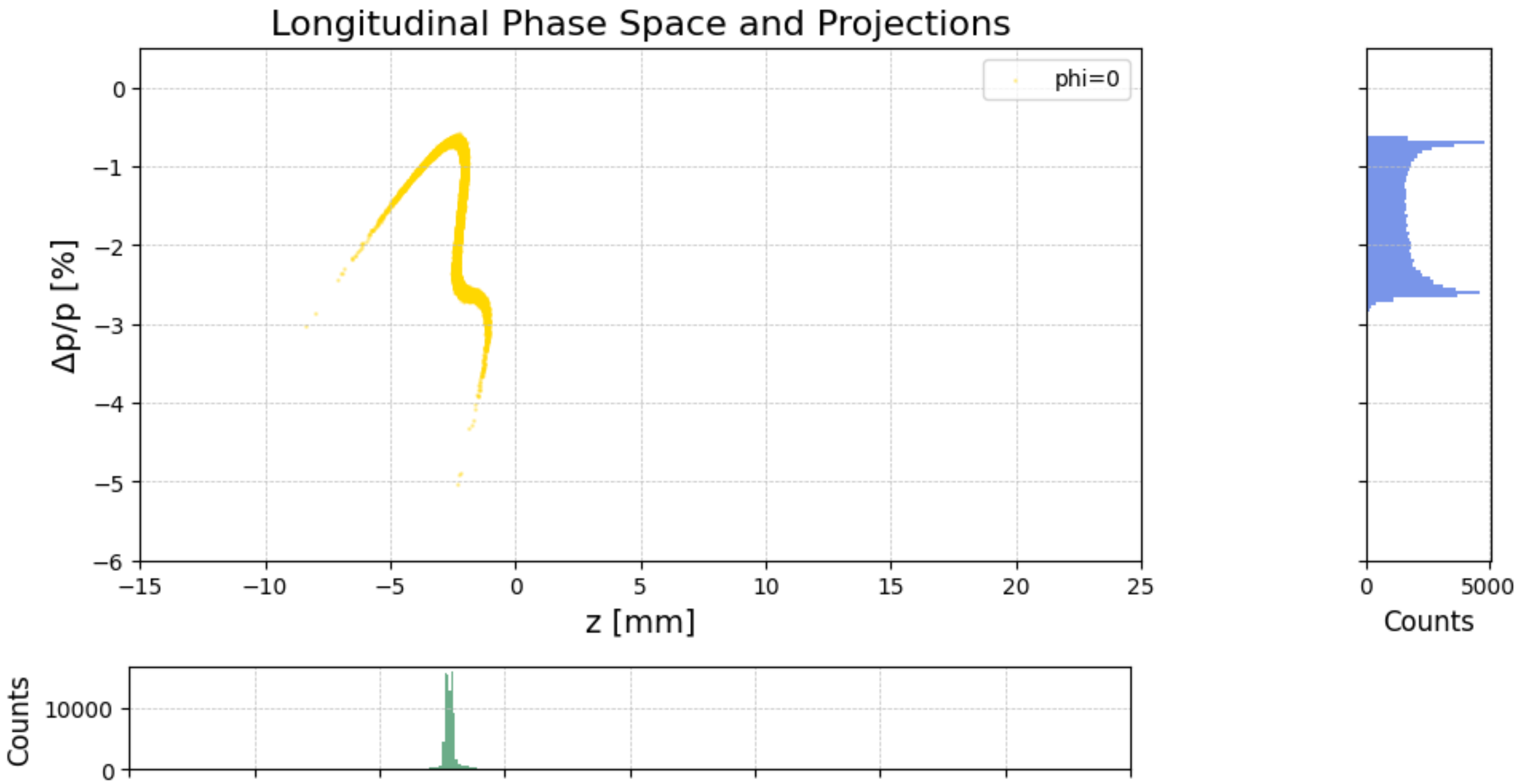


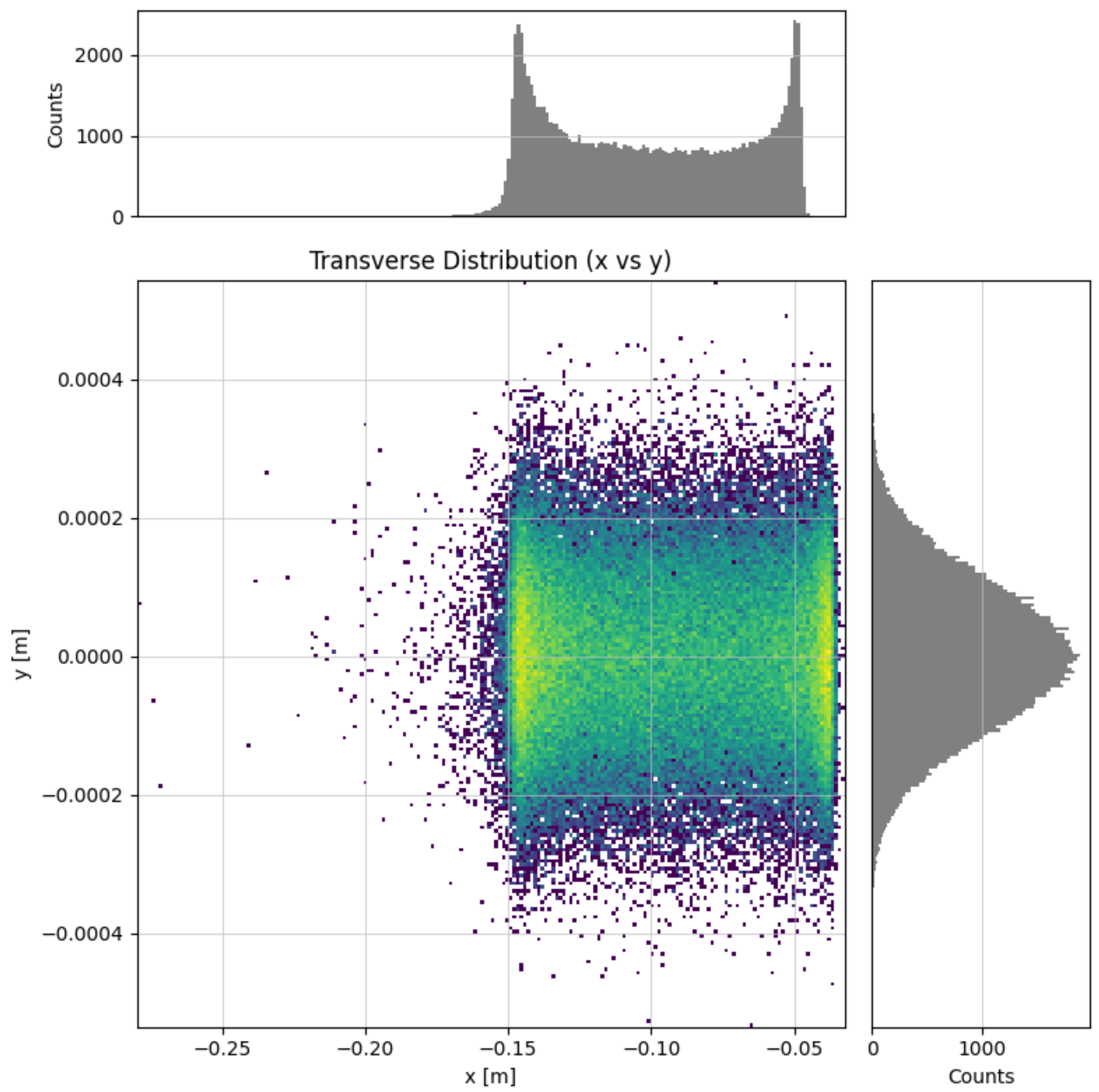


DESY.

“Recreating” DUMP line

Phi=0

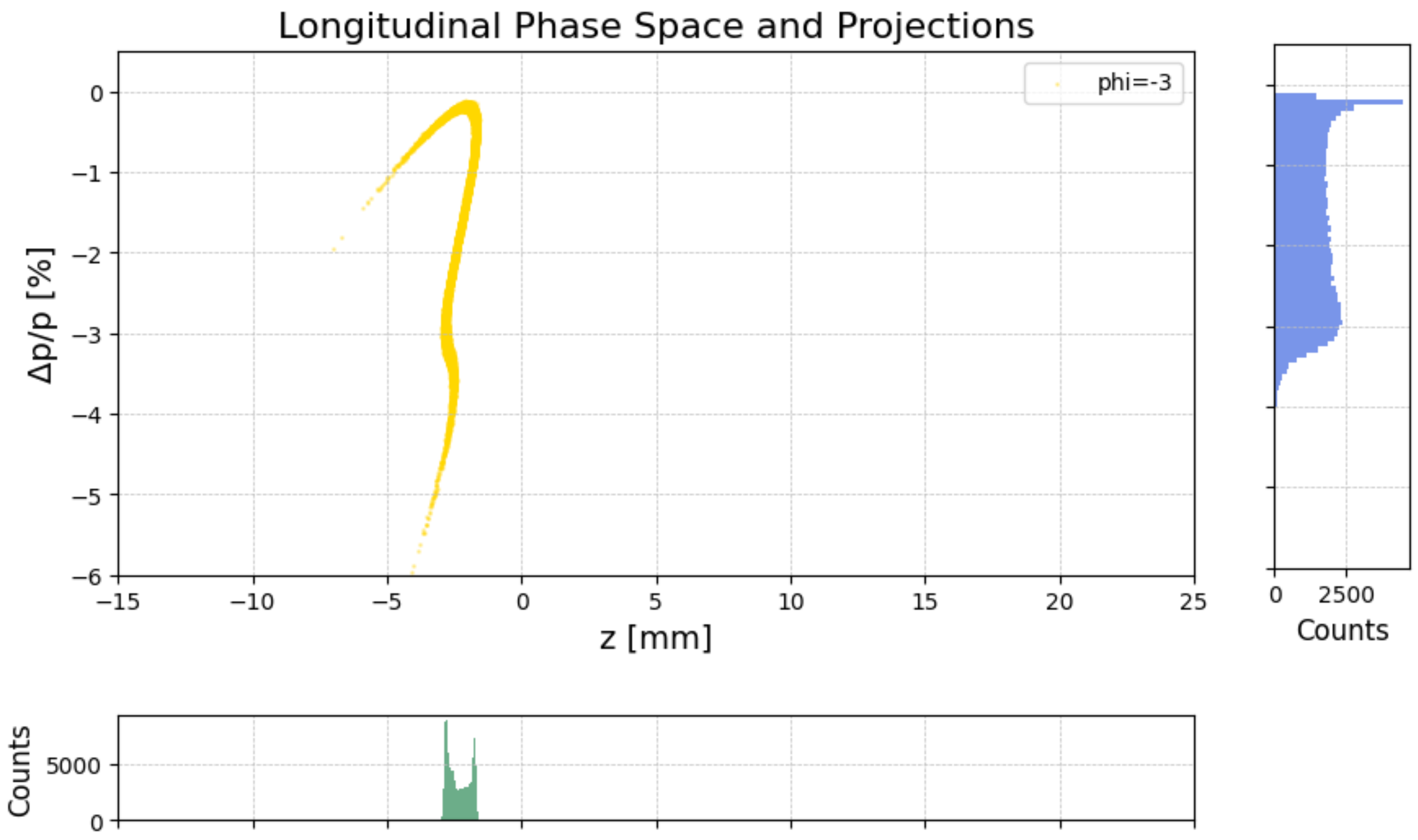


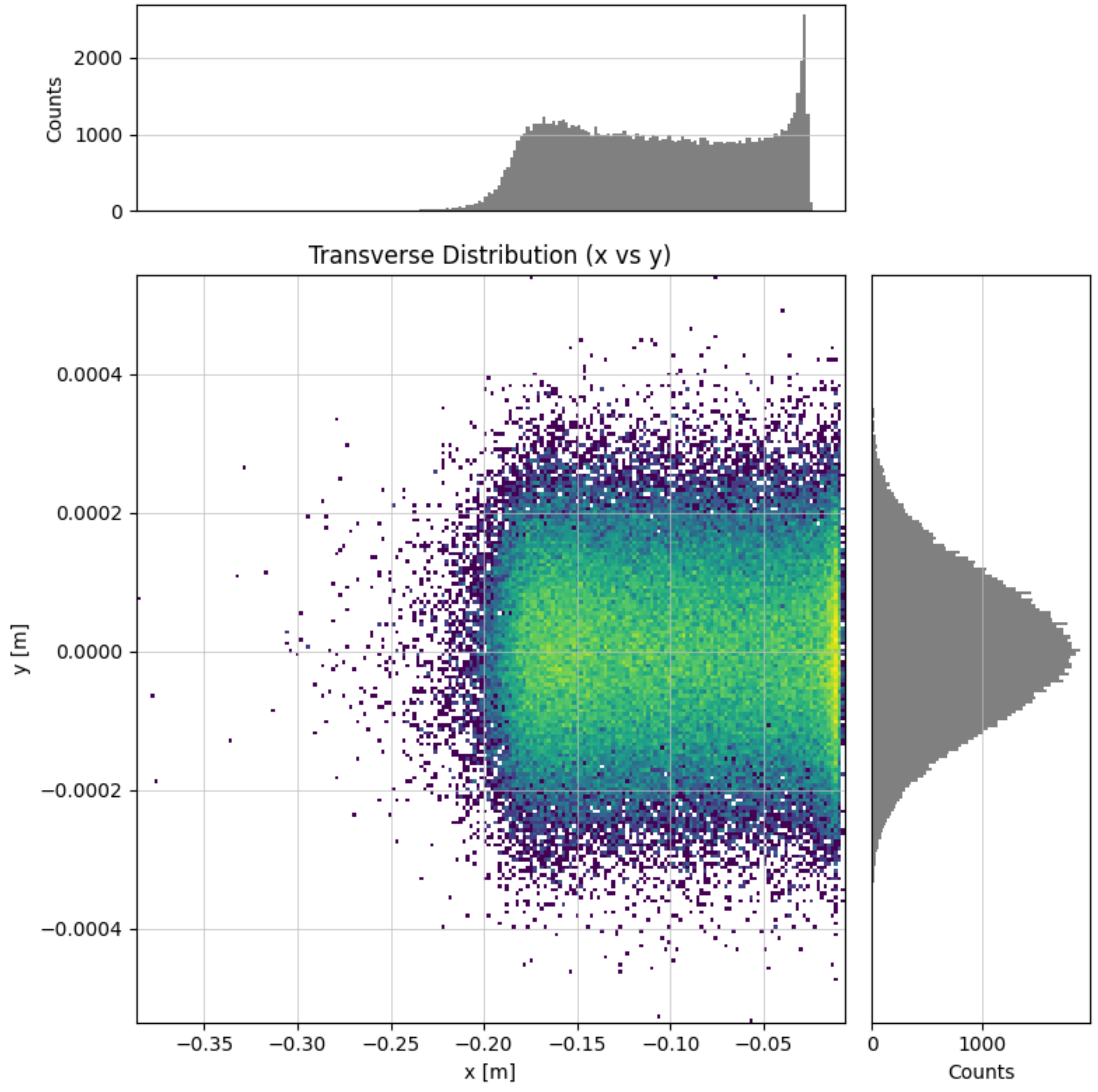


DESY.

“Recreating” DUMP line

Phi=-3

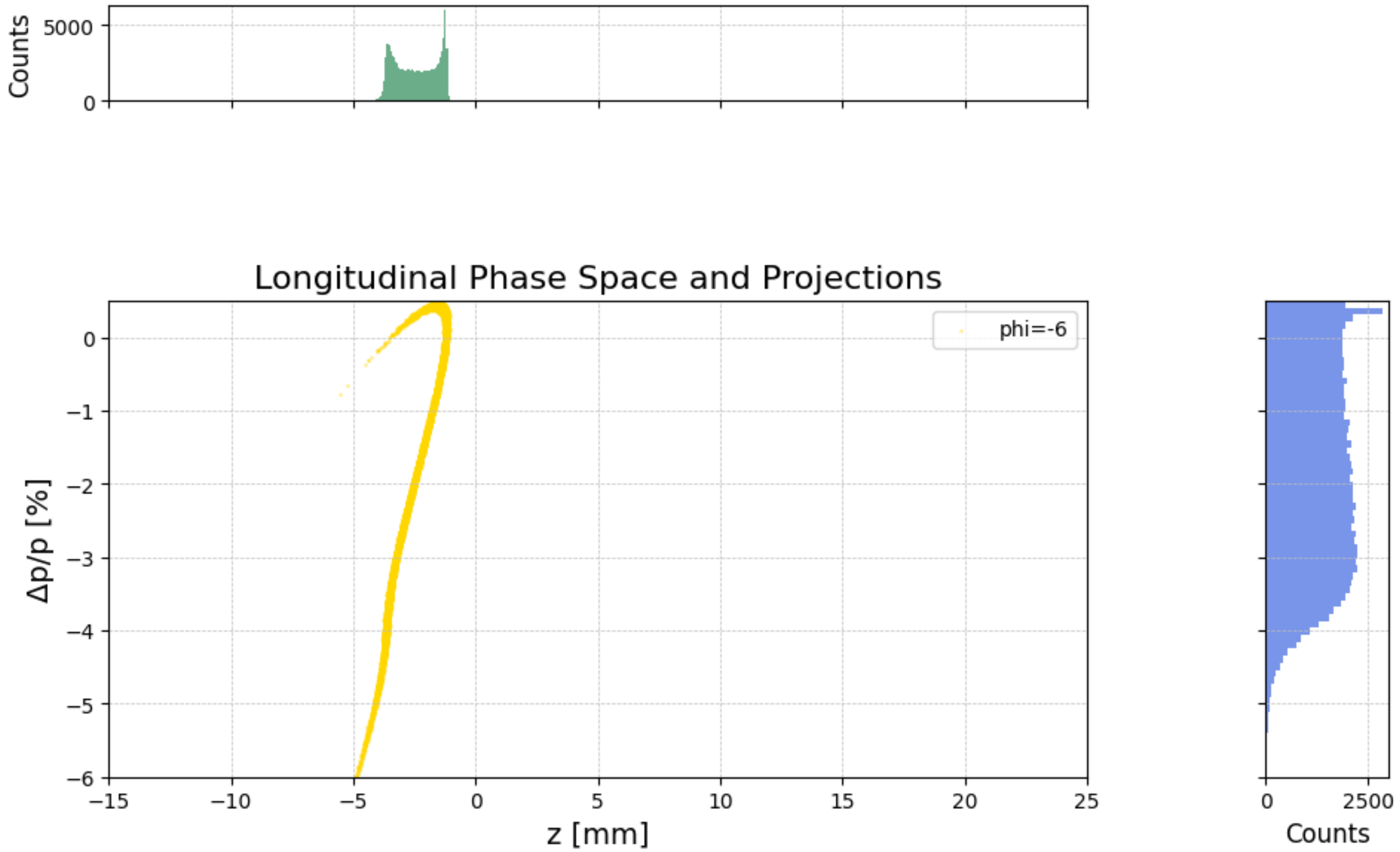


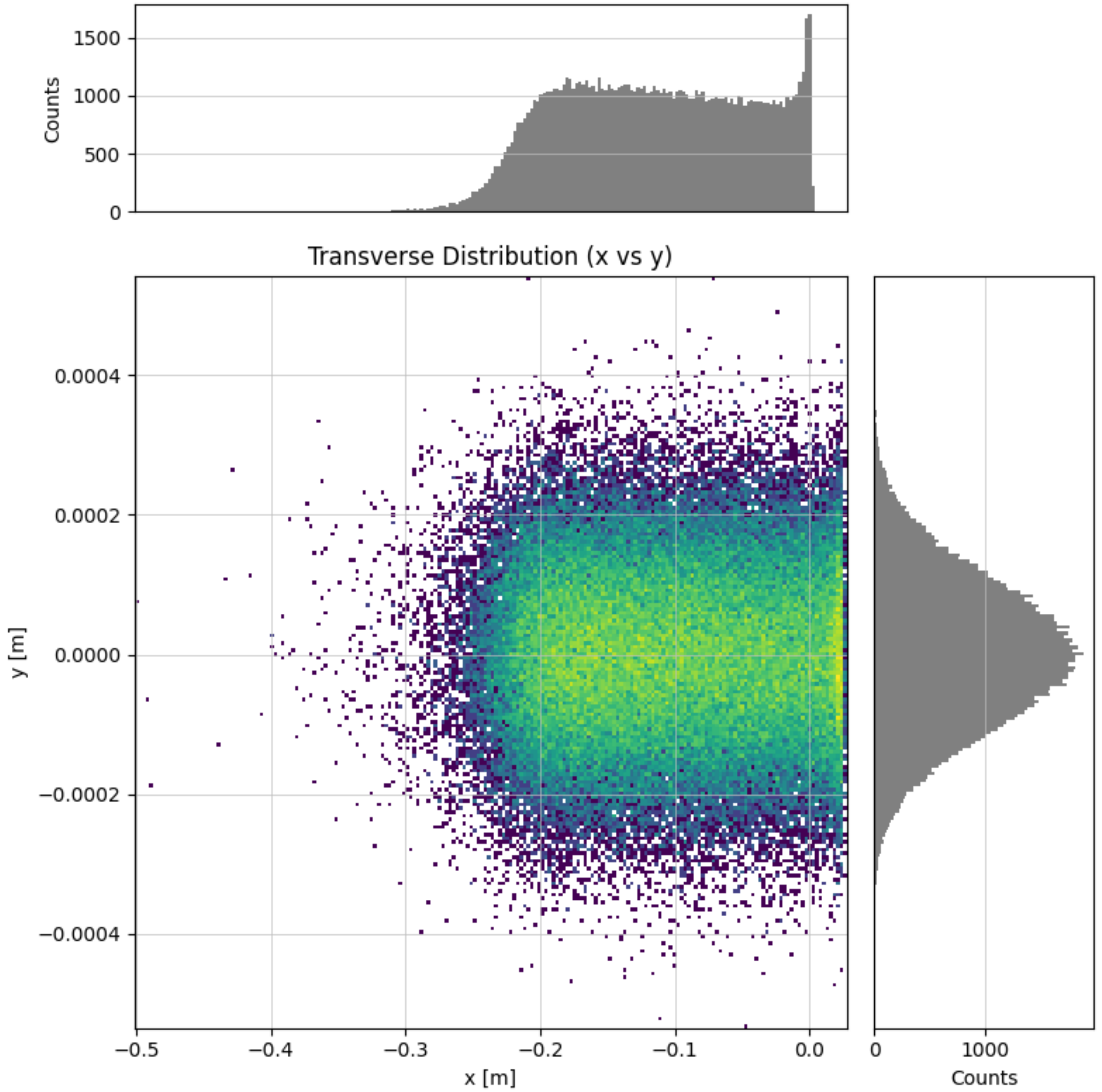


“Recreating” DUMP line

*comment

Phi=-6



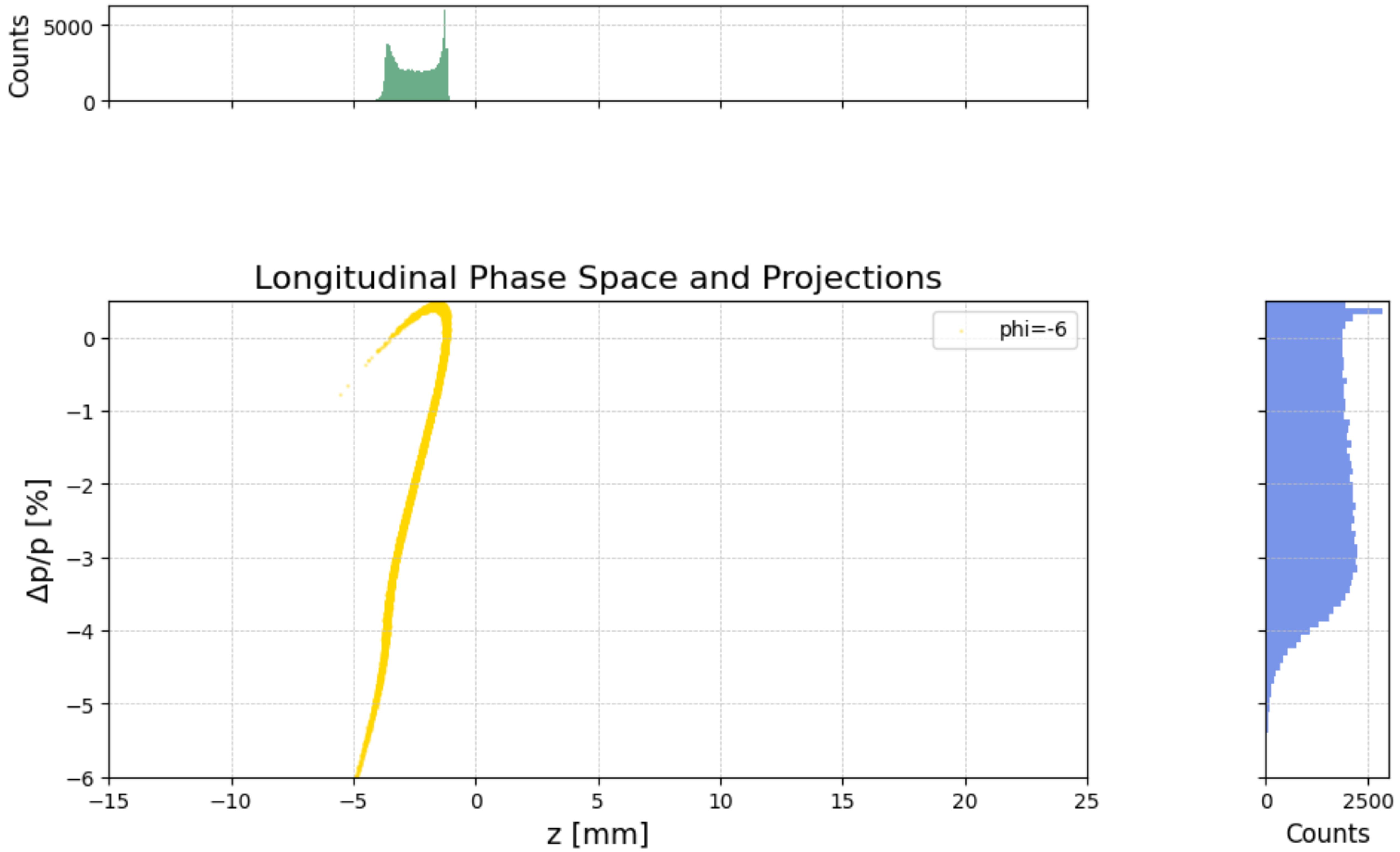


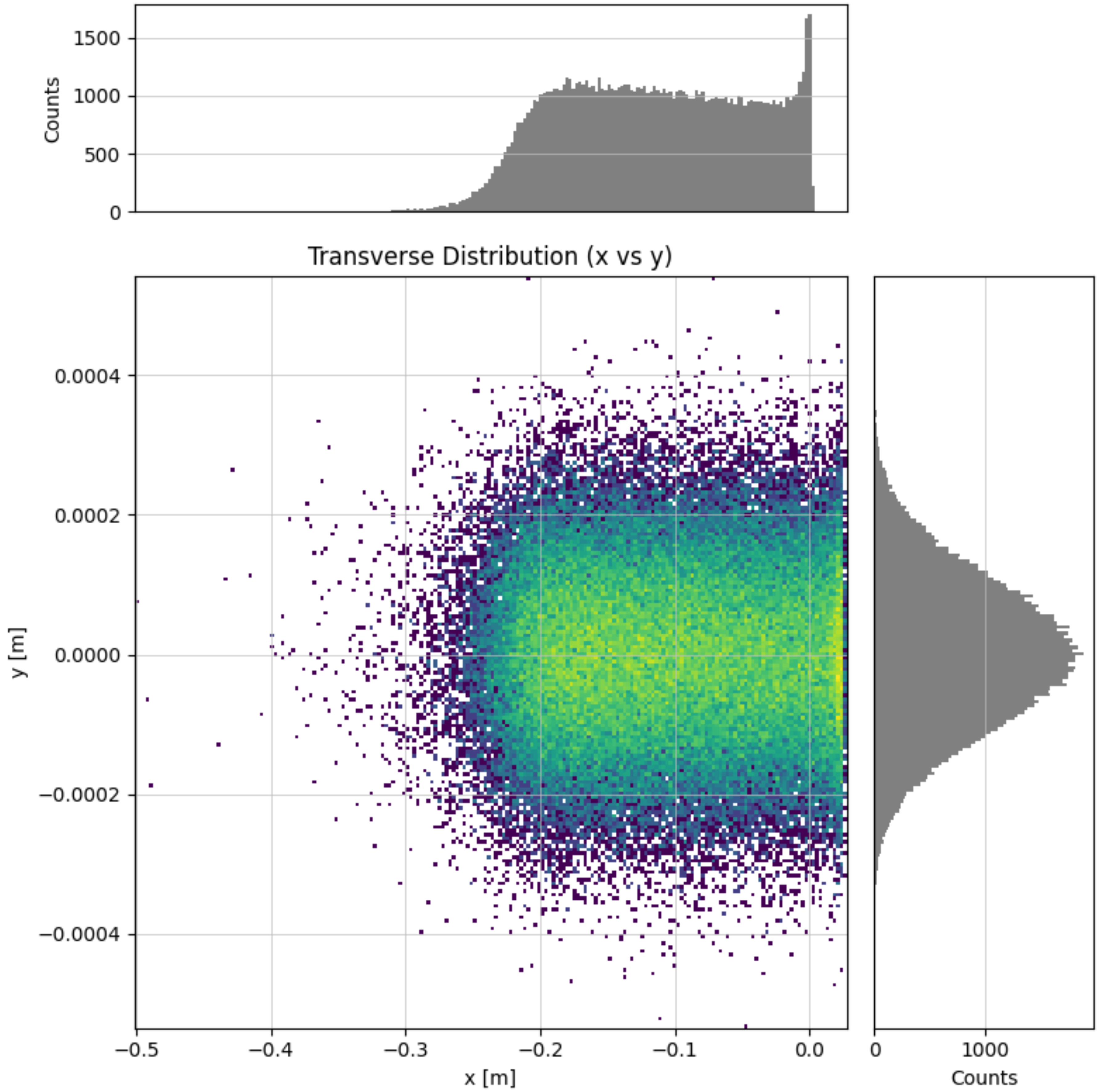
DESY.

“Recreating” DUMP line

*comment

Phi=-6





Simulations show that depending on the RF phase (ϕ = +3°, 0°, –3°, –6°), the longitudinal double-peak distribution can project into the transverse plane.

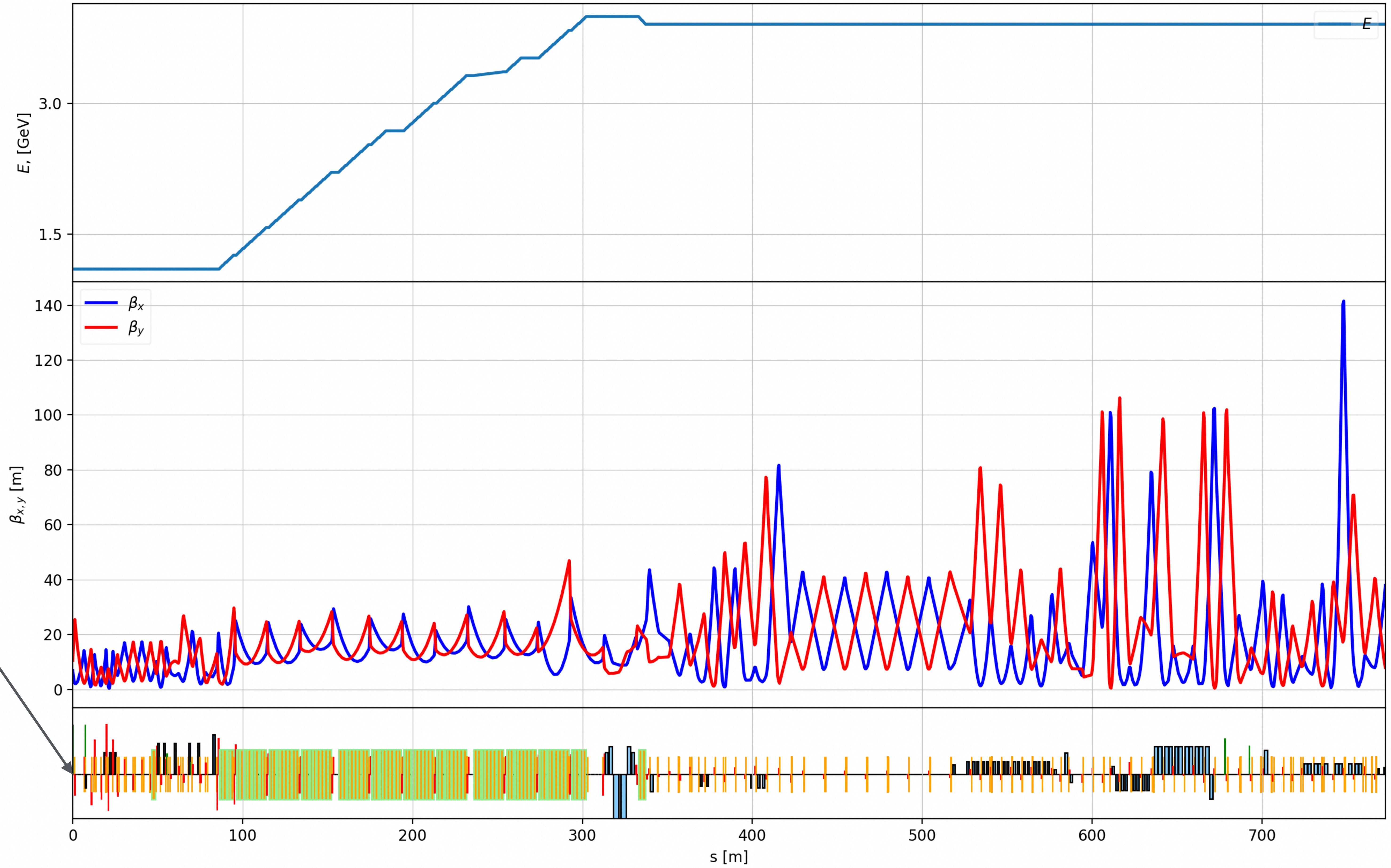
DESY.

SuperKEKB injection meeting

- **Initial tracking of BTp and comparison to ring acceptance**

For positrons we have:

RTL



Injection to LER

LER PARAMETERS

2017/September/1	LER	HER	unit	
E	4.000	7.007	GeV	
I	3.6	2.6	A	
Number of bunches	2,500			
Bunch Current	1.44	1.04	mA	
Circumference	3,016.315		m	
$\varepsilon_x/\varepsilon_y$	3.2(1.9)/8.64(2.8)	4.6(4.4)/12.9(1.5)	nm/pm	():zero current
Coupling	0.27	0.28		includes beam-beam
β_x^*/β_y^*	32/0.27	25/0.30	mm	
Crossing angle	83		mrad	
α_p	3.20×10^{-4}	4.55×10^{-4}		
σ_δ	$7.92(7.53)\times10^{-4}$	$6.37(6.30)\times10^{-4}$		():zero current
V_c	9.4	15.0	MV	
σ_z	6(4.7)	5(4.9)	mm	():zero current
ν_s	-0.0245	-0.0280		
ν_x/ν_y	44.53/46.57	45.53/43.57		
U_0	1.76	2.43	MeV	
$\tau_{x,y}/\tau_s$	45.7/22.8	58.0/29.0	msec	
ξ_x/ξ_y	0.0028/0.0881	0.0012/0.0807		
Luminosity	8×10^{35}		$cm^{-2}s^{-1}$	

https://www-superkekb.kek.jp/

$$\boxed{\alpha_p = \frac{\Delta L/L}{\Delta p/p}}$$

In mail: 3.25e-4

$$\boxed{\begin{aligned}\sigma_z &= 4.7\ \text{mm}\\ \sigma_\delta &= 7.53\times10^{-4}\end{aligned}}$$

DESY.

LER PARAMETERS

Table 1: RF-related machine parameters achieved at KEKB [12] and those of the design values in SuperKEKB [6].

Parameters	Unit	KEKB (achieved)				SuperKEKB (design)			
		LER	HER			LER		HER	
Beam energy	GeV	3.5		8.0		4.0		7.0	
Beam current	A	2.0		1.4		3.6		2.6	
Bunch length	mm	6–7		6–7		6		5	
Number of bunch		1585		1585		2500		2500	
Total RF voltage	MV	8		13–15		10–11		15	
Energy loss/turn	MV	1.6		3.5		1.76		2.43	
Total beam power	MW	3.3		5.0		~8		~8	
RF frequency	MHz		508.9					508.9	
Revolution frequency	kHz		99.4					99.4	
Cavity type		ARES	ARES		SCC	ARES		ARES	SCC
No. of cavities		20	10	2	8	8	14	8	8
Klystron : cavities		1:2	1:2	1:1	1:1	1:2	1:1	1:1	1:1
No. of klystron stations		10	5	2	8	4	14	8	8
RF voltage/cavity	MV	0.4	0.31	0.31	1.24	~0.5	~0.5	~0.5	1.3–1.5
Beam poser/cavity	kW	200	200	550	400	200	600	600	400
R/Q of cavity	Ω	15	15	15	93	15	15	15	93
Loaded Q (Q_L)	$\times 10^4$	3	3	1.7	~5	3	1.7	1.7	~5

https://accelconf.web.cern.ch/eefact2022/papers/wexas0102.pdf

$$h = \frac{f_{\mathrm{RF}}}{f_{\mathrm{rev}}} \approx \mathbf{5120}$$

The operation phases of LINAC and MR are not always coincide since their RF frequencies are different (2856MHz and 508.9MHz, respectively).

DESY.

LER PARAMETERS

Table 1: RF-related machine parameters achieved at KEKB [12] and those of the design values in SuperKEKB [6].

Parameters	Unit	KEKB (achieved) LER	HER			SuperKEKB (design) LER		HER	
Beam energy	GeV	3.5	8.0			4.0		7.0	
Beam current	A	2.0	1.4			3.6		2.6	
Bunch length	mm	6–7	6–7			6		5	
Number of bunch		1585	1585			2500		2500	
Total RF voltage	MV	8	13–15			10–11		15	
Energy loss/turn	MV	1.6	3.5			1.76		2.43	
Total beam power	MW	3.3	5.0			~8		~8	
RF frequency	MHz	508.9				508.9			
Revolution frequency	kHz	99.4				99.4			
Cavity type		ARES	ARES		SCC	ARES		ARES	SCC
No. of cavities		20	10	2	8	8	14	8	8
Klystron : cavities		1:2	1:2	1:1	1:1	1:2	1:1	1:1	1:1
No. of klystron stations		10	5	2	8	4	14	8	8
RF voltage/cavity	MV	0.4	0.31	0.31	1.24	~0.5	~0.5	~0.5	1.3–1.5
Beam poser/cavity	kW	200	200	550	400	200	600	600	400
R/Q of cavity	Ω	15	15	15	93	15	15	15	93
Loaded Q (Q_L)	$\times 10^4$	3	3	1.7	~5	3	1.7	1.7	~5

https://accelconf.web.cern.ch/eefact2022/papers/wexas0102.pdf

$$\nu_s = \sqrt{\frac{h\,e\,V_{\mathrm{rf}}\,|\cos\phi_s|}{2\pi\,\beta^2\,E}}\cdot\eta$$

$$= \sqrt{\frac{5120\cdot(1.602\times10^{-19})\cdot(10.5\times10^{6})\cdot 1}{2\pi\cdot(4.0\times10^{9})}}\cdot(-0.0012)$$

$$\Rightarrow \boxed{\nu_s \approx -0.0247}$$

*same number as given in email

DESY.

Task: Try to see the 2-dimensional Z[i], E[i] distribution after subtracting the center-of-gravity values and compare with the ellipse:

$$\left(\frac{Z}{Z_{\text{limit}}}\right)^2 + \left(\frac{E}{E_{\text{limit}}}\right)^2 = 1$$

Then the ellipse is:

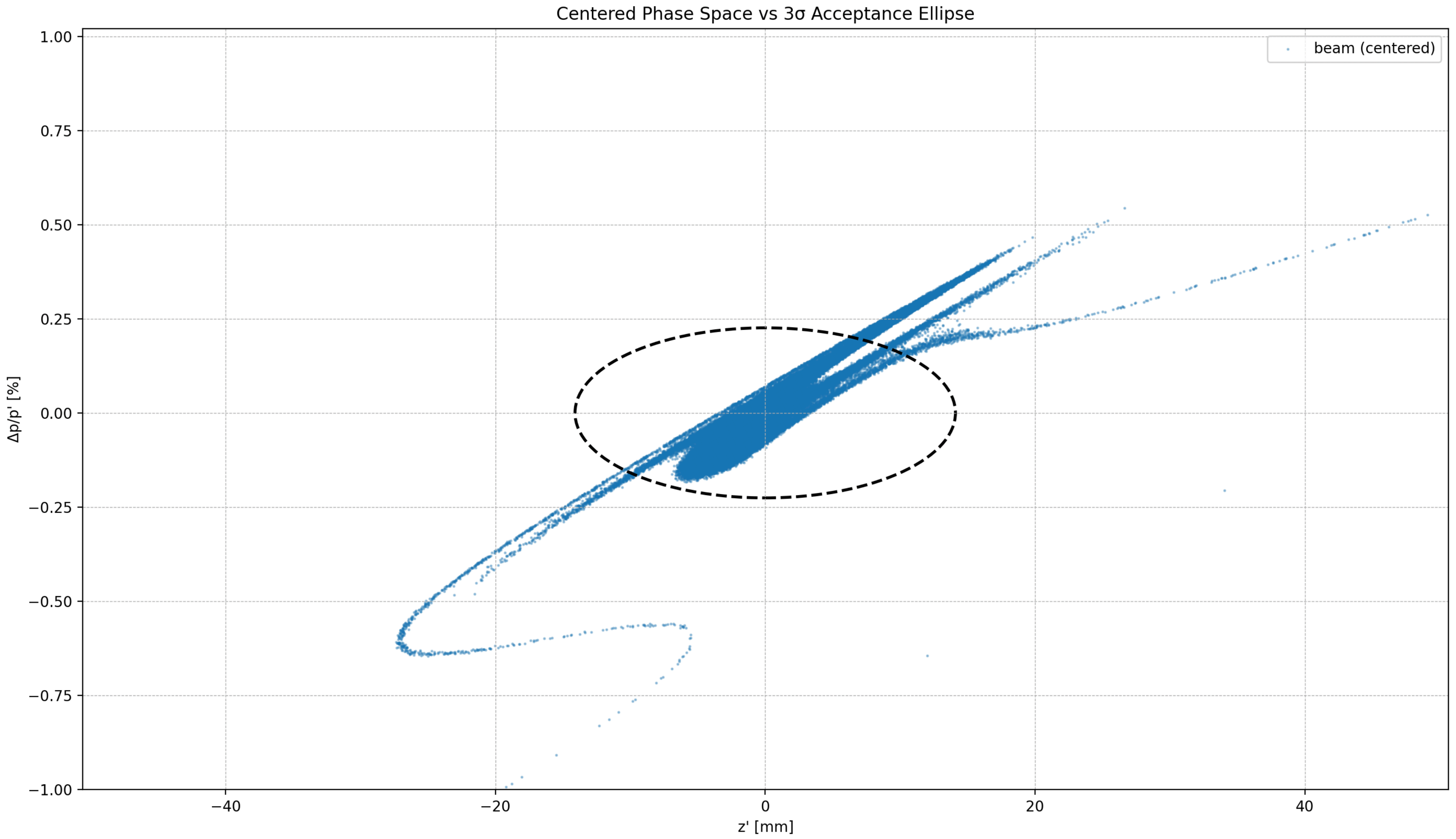
$$\left(\frac{Z}{n\,\sigma_z}\right)^2 + \left(\frac{\delta}{n\,\sigma_d}\right)^2 = 1$$

Example (3σ contour):

- $Z_{\text{limit}} = 3 \times 4.7\ \text{mm} = 14.1\ \text{mm}$
- $\delta_{\text{limit}} = 3 \times 7.53 \times 10^{-4} = 2.26 \times 10^{-3}$

BEFORE OPT

```
amplitudBCS = 0.0184
LinacPhase= 5
amplitudECS  = 0.044
```

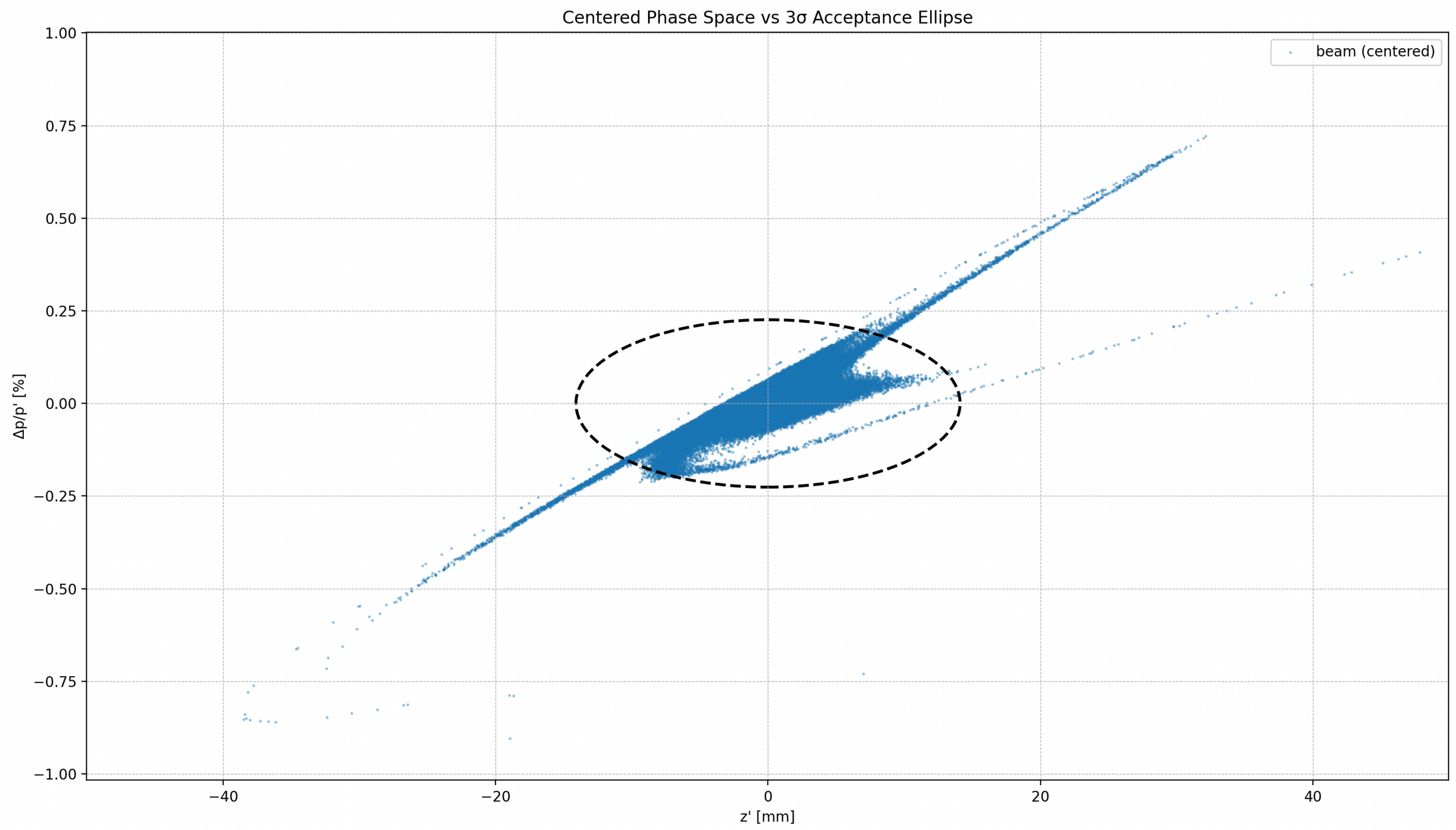


91.64% of the charge lies inside the 3σ ellipse.
Center of gravity before centering:

z_cg = −30.265 mm,
dp/p_cg = −6.653e−03

97.11% of the charge lies inside the 3σ ellipse.
Center of gravity before centering:

z_cg = −28.512 mm,
dp/p_cg = −6.193e−03



Best amplitud1: 0.02100
Best LinacPhase: 0.00000 rad (0.00 deg)
Best amplitud2: 0.04400

AFTER OPT

DESY.

HER Example: Y. Funakoshi et al 2024 JINST 19 T02003

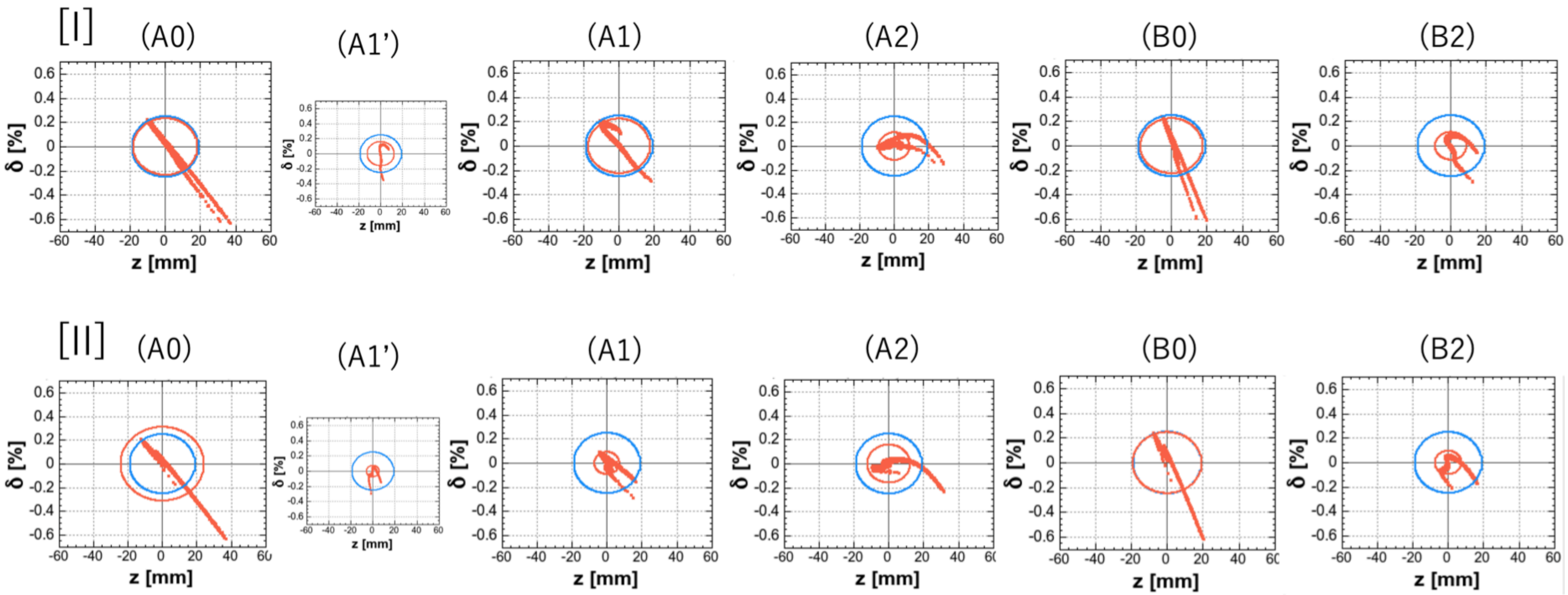


Figure 28. Simulated particle distribution of particles at the HER injection point. Orange dots show 10,000 particles transported from LINAC, and the orange ellipse contains 95 % of the injected particles. We call this orange ellipse as beam ellipse. The blue ellipse is ring acceptance determined by the dynamic aperture, which accepts 95 % of injected particles to the HER. (z, and δ) are the longitudinal coordinates. [I] and [II] represent $\Delta\phi_{\mathrm{RF}}$ of $-4°$ and $0°$, respectively. (A0) to (B2) show the different BT lines. (A) shows the present BT line, (B) shows the new BT line, and the number (0), (1), (2) represents without ECS, with ECS1, and with ECS2, respectively. (A1′) is the distribution just after the ECS1.

1D longitudinal-motion model

Blue line shows how, over time, the particle's longitudinal position z and relative momentum deviation oscillate under the RF "kick."

Machine

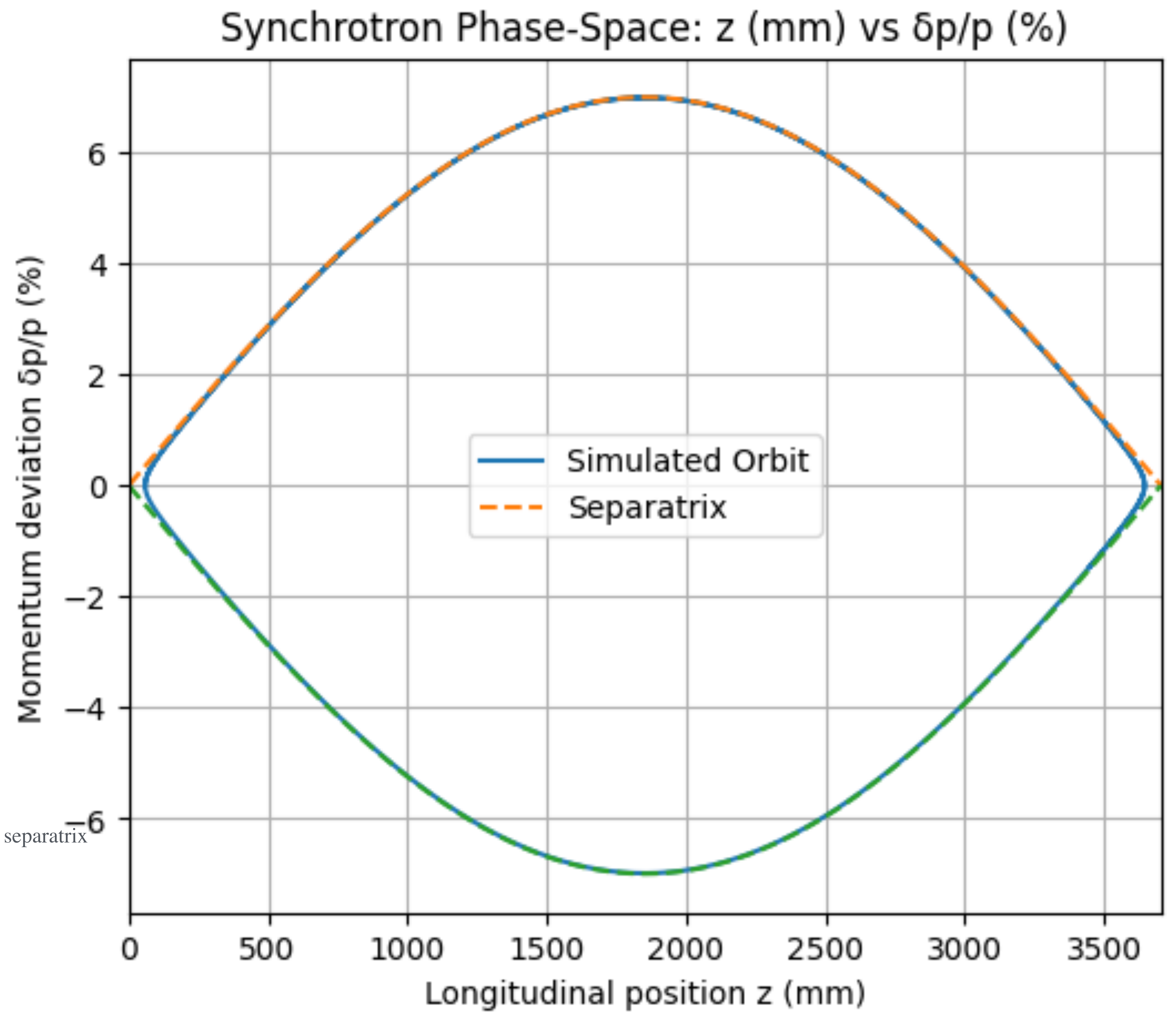
RF voltage: 8 MV

RF frequency: 508.9 MHz

Circumference: 3016 m

Momentum compaction $\alpha = 3.2\times10^{-4}$

Beam energy: 4 GeV



Derived constants:

$$T_{\text{rev}} = \frac{L}{c}, \quad K = \frac{L\,\alpha\,f_{\text{RF}}}{T_{\text{rev}}\,c}, \quad M = \frac{V_{\text{RF}}}{T_{\text{rev}}\,E_0}, \quad \omega_s = \sqrt{\frac{V_{\text{RF}}\,L\,\alpha\,f_{\text{RF}}}{T_{\text{rev}}^2\,c\,E_0}}$$

We then integrate the coupled ODEs

Longitudinal equations:

$$\begin{cases} \dot{\varphi} = K\,\delta, \\ \dot{\delta} = M\,\sin\varphi. \end{cases}$$

→ solved with 4th-order Runge–Kutta ($\Delta t = 0.1\,\mu s$, 50 000 steps)

convert phase to longitudinal position z (mm) and momentum deviation to δp/p (%), and overlay the result on the analytical separatrix

Separatrix:

$$\delta_{\text{sep}}(\varphi) = \frac{\sqrt{2}\,\omega_s}{K}\,\sqrt{1-\cos\varphi}$$

Overlay $\pm\delta_{\text{sep}}$ on $\phi\to z$ vs. $\delta p/p$.

DESY.

LER: Longitudinal phase space at injection

Compute the two branches of the single-harmonic RF bucket separatrix in z (mm) vs. δ.

Finds the synchrotron phase ϕs from

$$\sin\phi_s \;=\; \frac{U_0}{V_{\rm rf}}$$

Solves for the boundary where particles are just captured in the bucket.

Linac phase

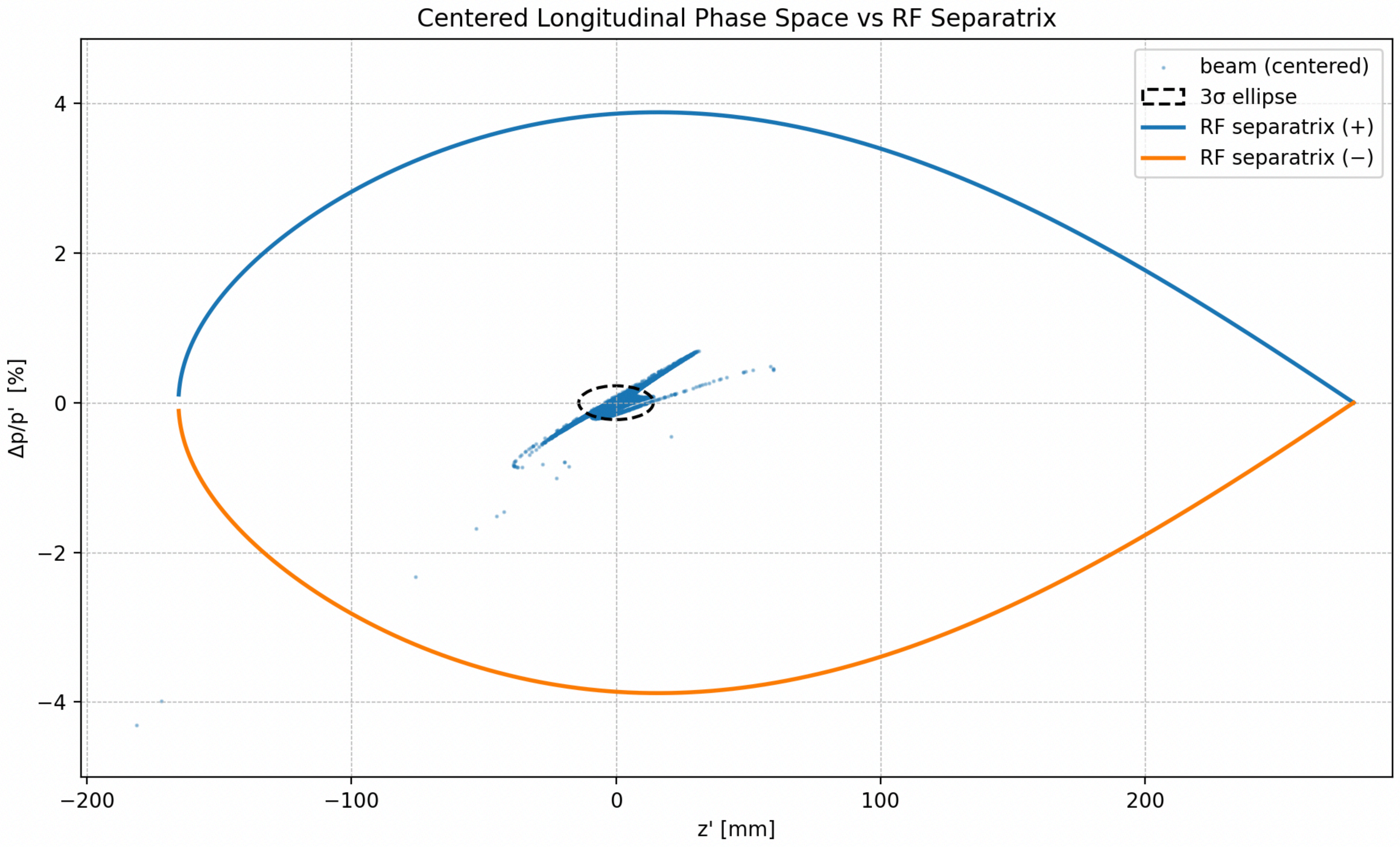
To maintain a stable circulation, the synchronous particle must satisfy

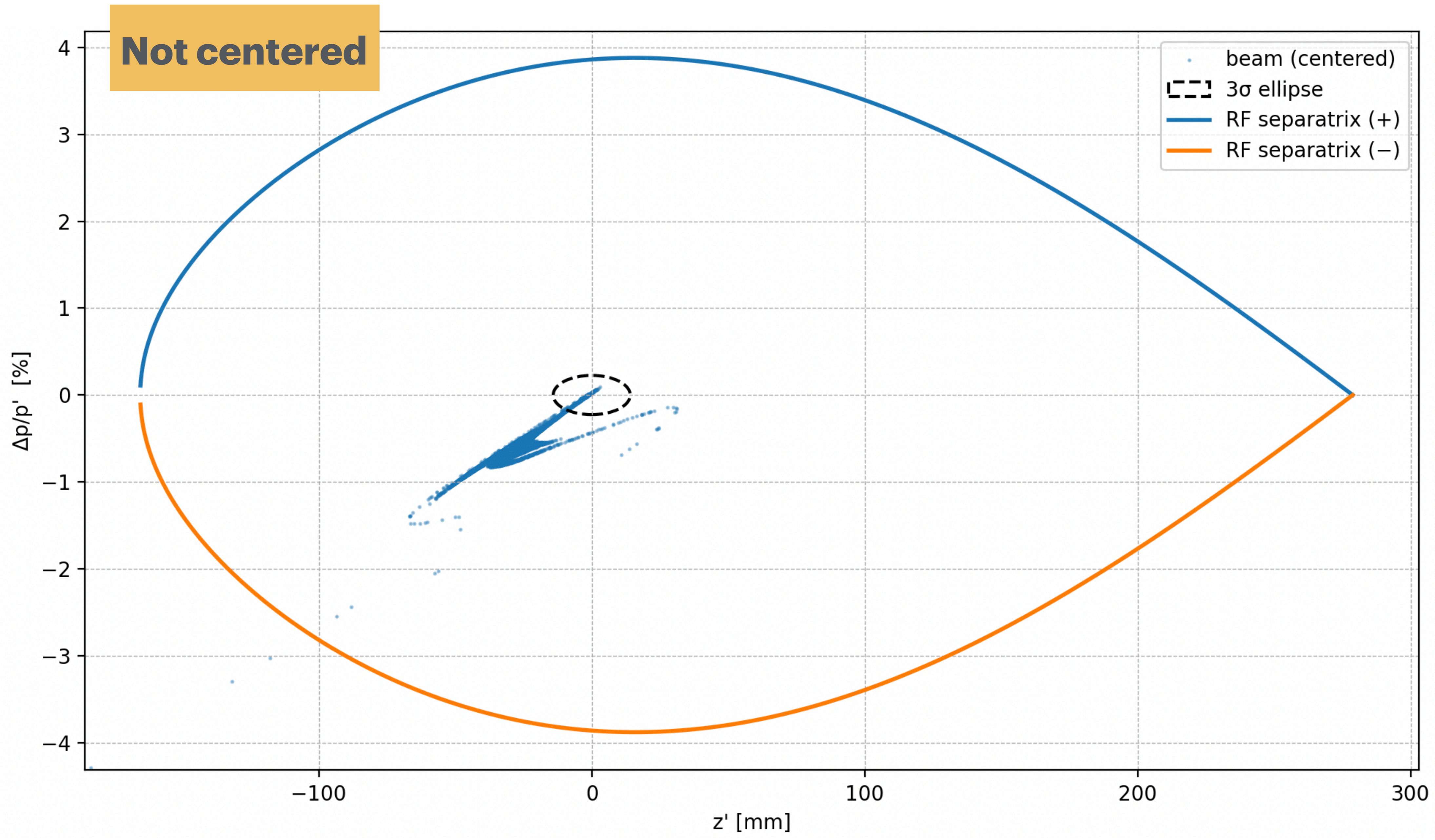
$$V_{\rm rf}\,\sin\phi_s \;=\; U_0$$

since it needs exactly U_0 of kick to replace its losses. Rearranging,

$$\sin\phi_s \;=\; \frac{U_0}{V_{\rm rf}} \quad\Longrightarrow\quad \phi_s \;=\; \arcsin\!\left(\tfrac{U_0}{V_{\rm rf}}\right).$$

What is the number of transverse acceptance



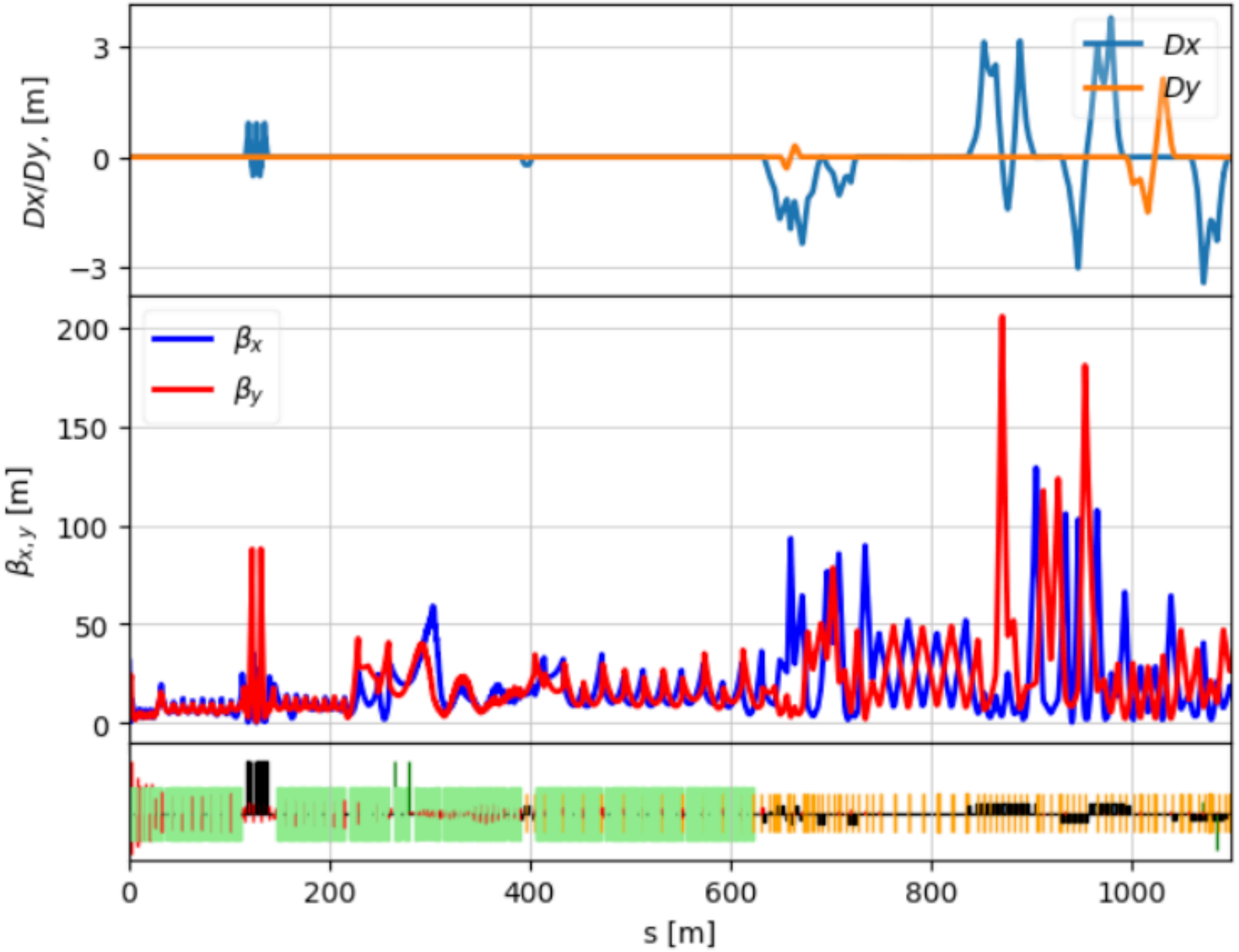


Is this really the case? Or is there an energy compensation with linac phase?

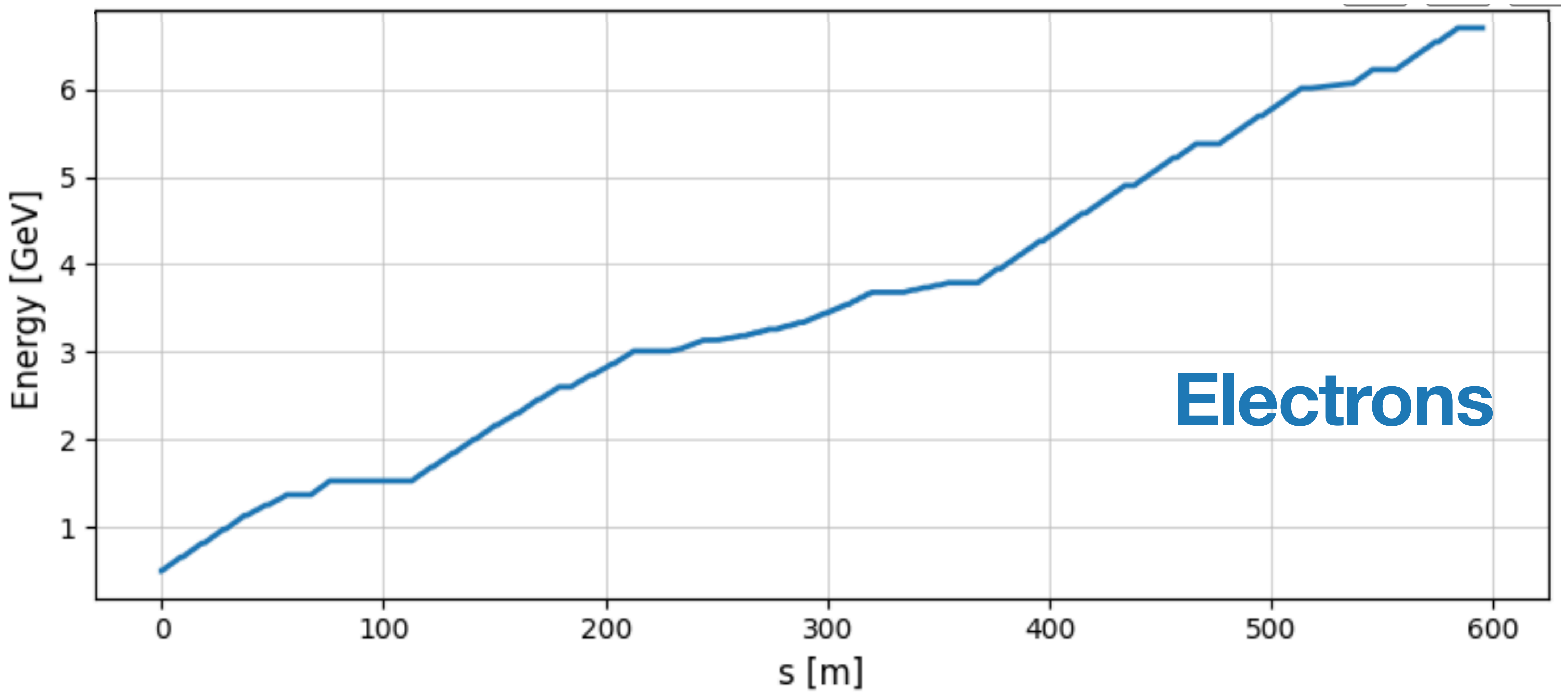
DESY.

For electrons: from SECTA w/o GUN in terms of simulation.

INITIAL DISTRIBUTION: GAUSSIAN



HER

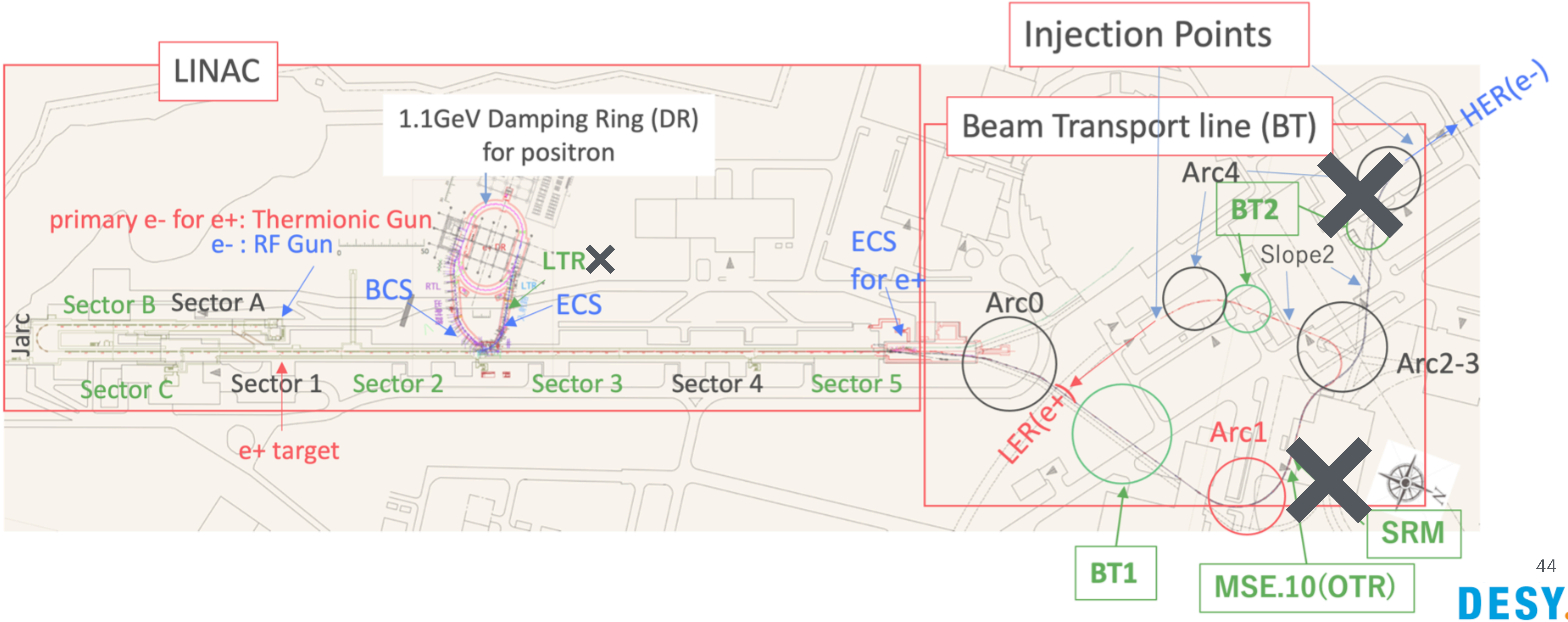


Electrons

DESY.

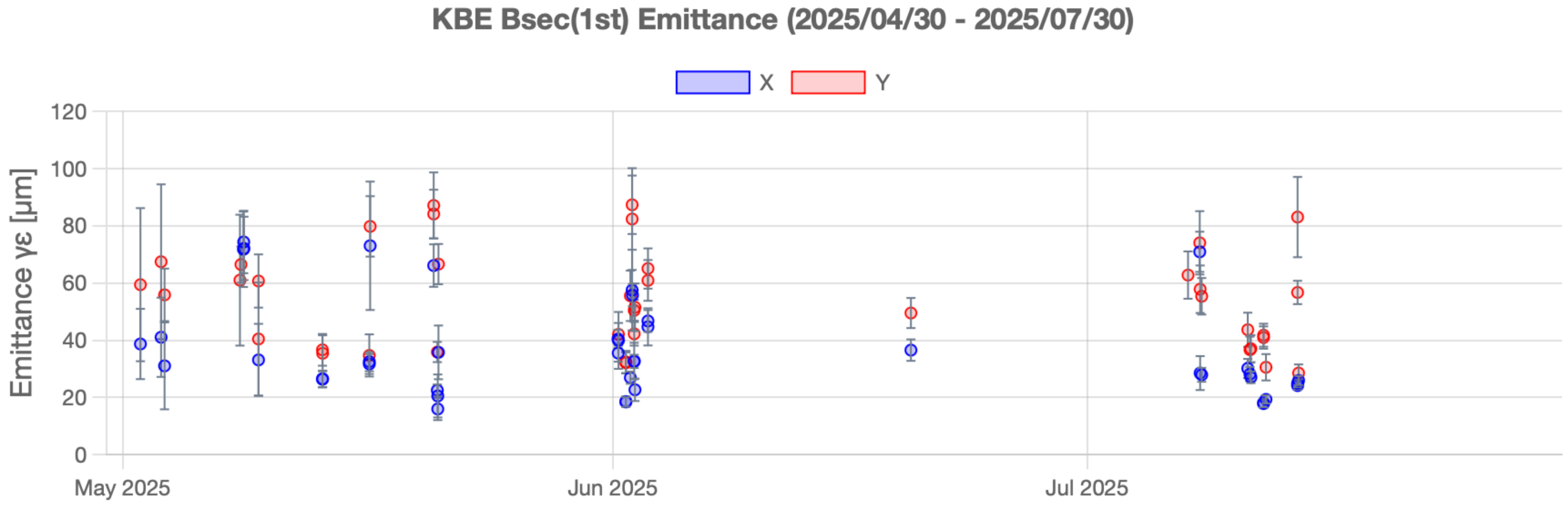
Measurements: ?

Wire scanners (WSs) and OTRs, are installed in the area shown in green, where the beam emittances can be measured.



DESY.

WIRE SCANNER



Thin wire that moves **across the beam path and as** passes through the beam, particles **interact with the wire**, producing **secondary radiation which a detector** measures at each wire position.

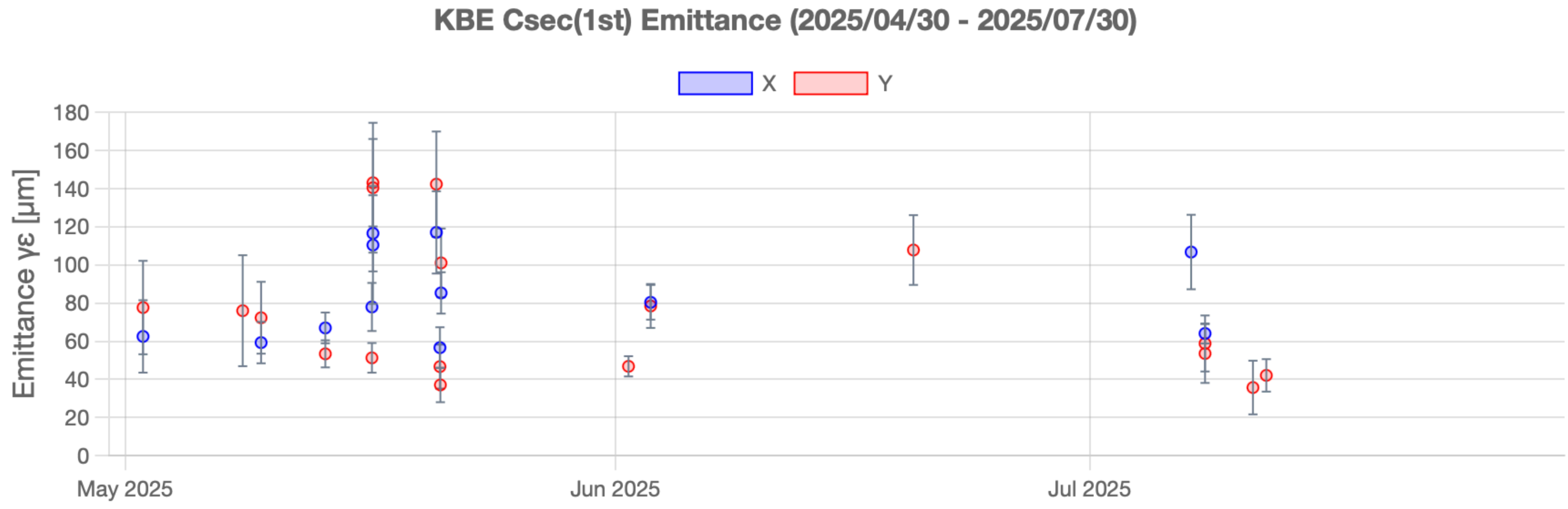
The **signal intensity** is proportional to the **beam density** at that position. Scanning across the full beam gives a **2D beam profile**

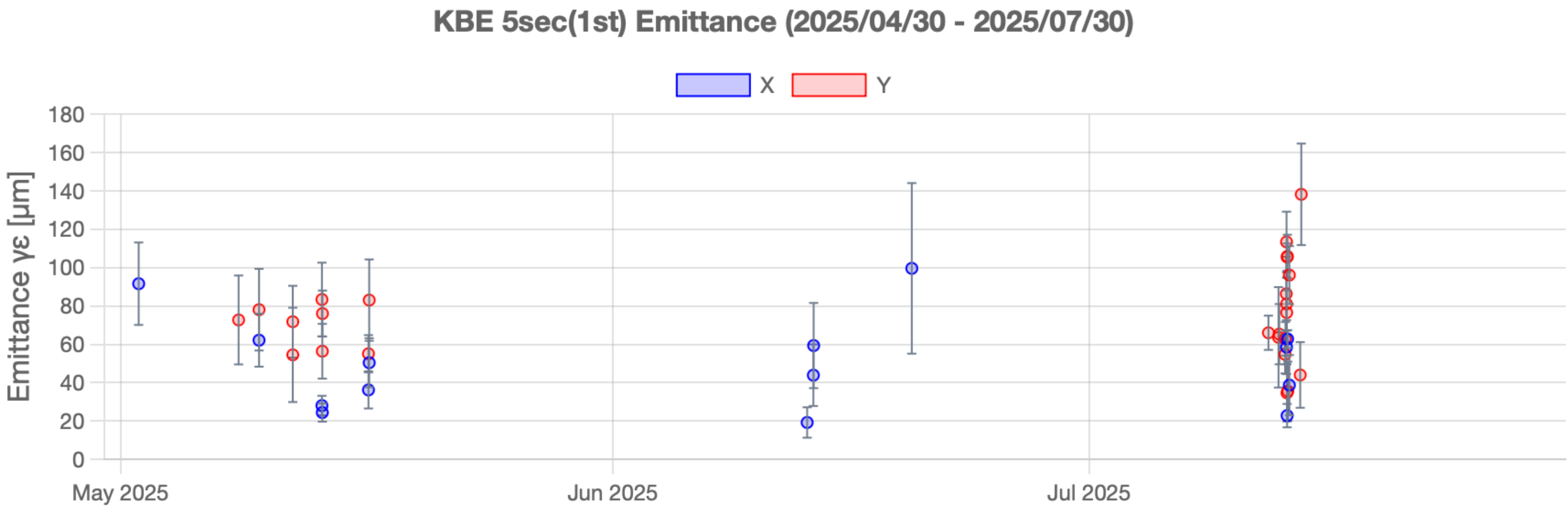
From the profile, one can extract the **beam size (σ)** and calculate **emittance** using optics parameters

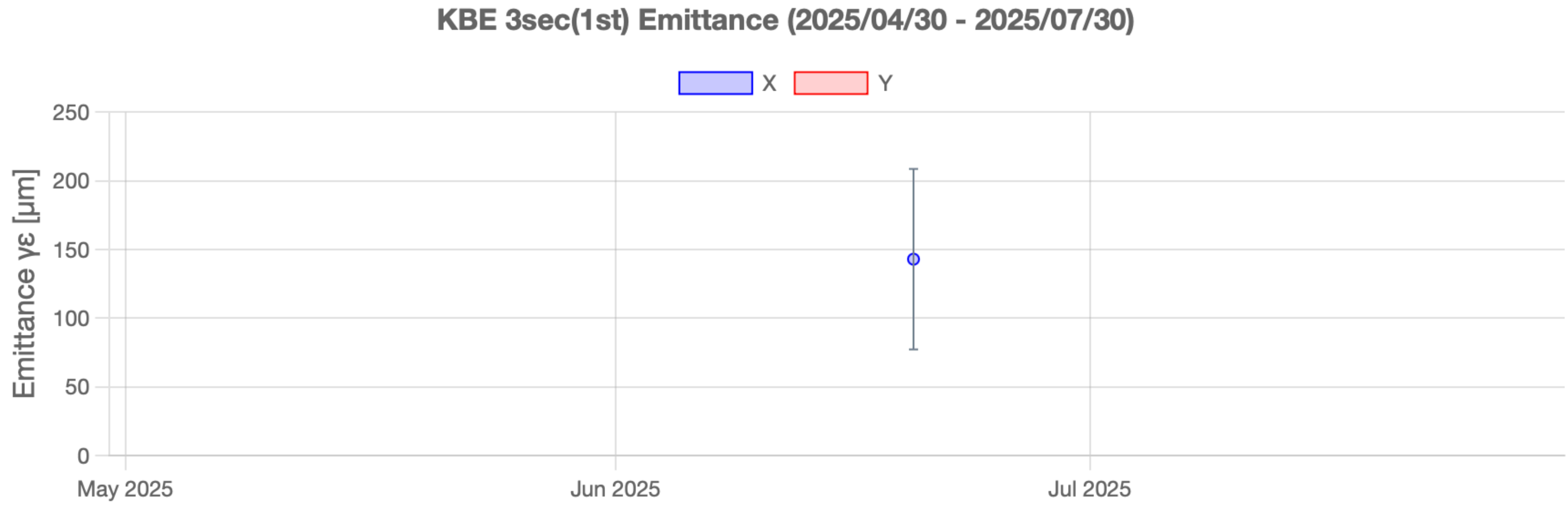
Beam Mode KBE **Bunch** 1st **Start date** 2025-07-30 **Time Span** -3months

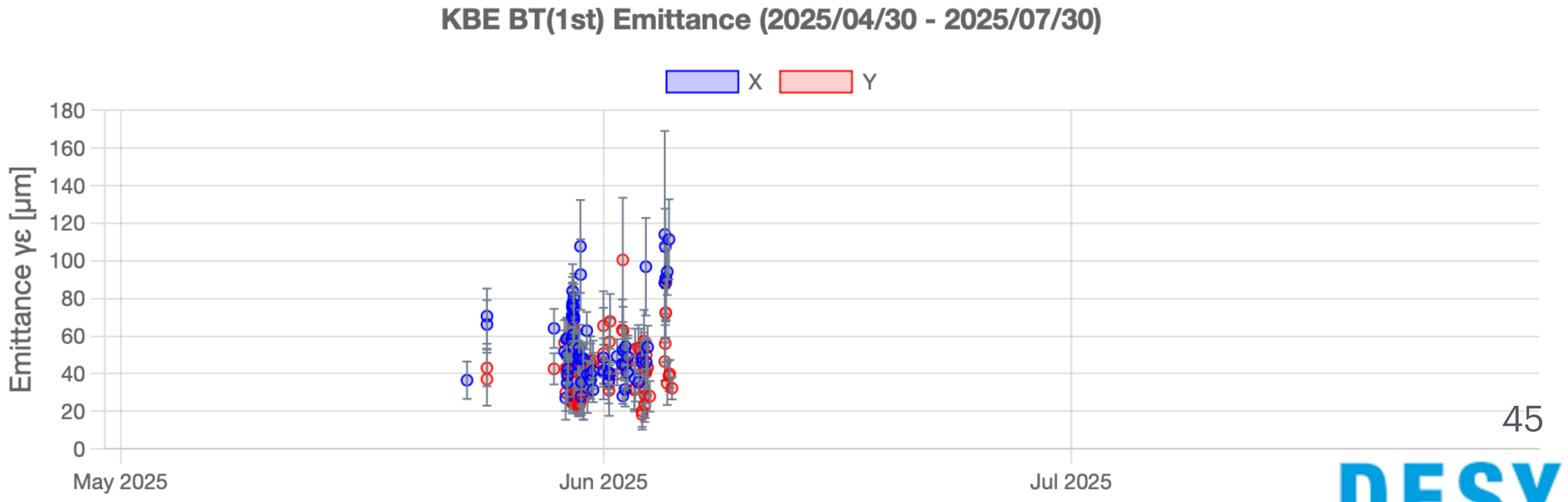
Sector Selection ☑ **Bsec** ☑ **Csec** ☑ **2sec** ☑ **LTR** ☑ **3sec** ☑ **5sec** ☑ **BT**

Wire Selection ☑ **3-wire:ABC** ☑ **3-wire:ABD** ☑ **3-wire:ACD** ☑ **3-wire:BCD** ☑ **4-wire:ABCD**









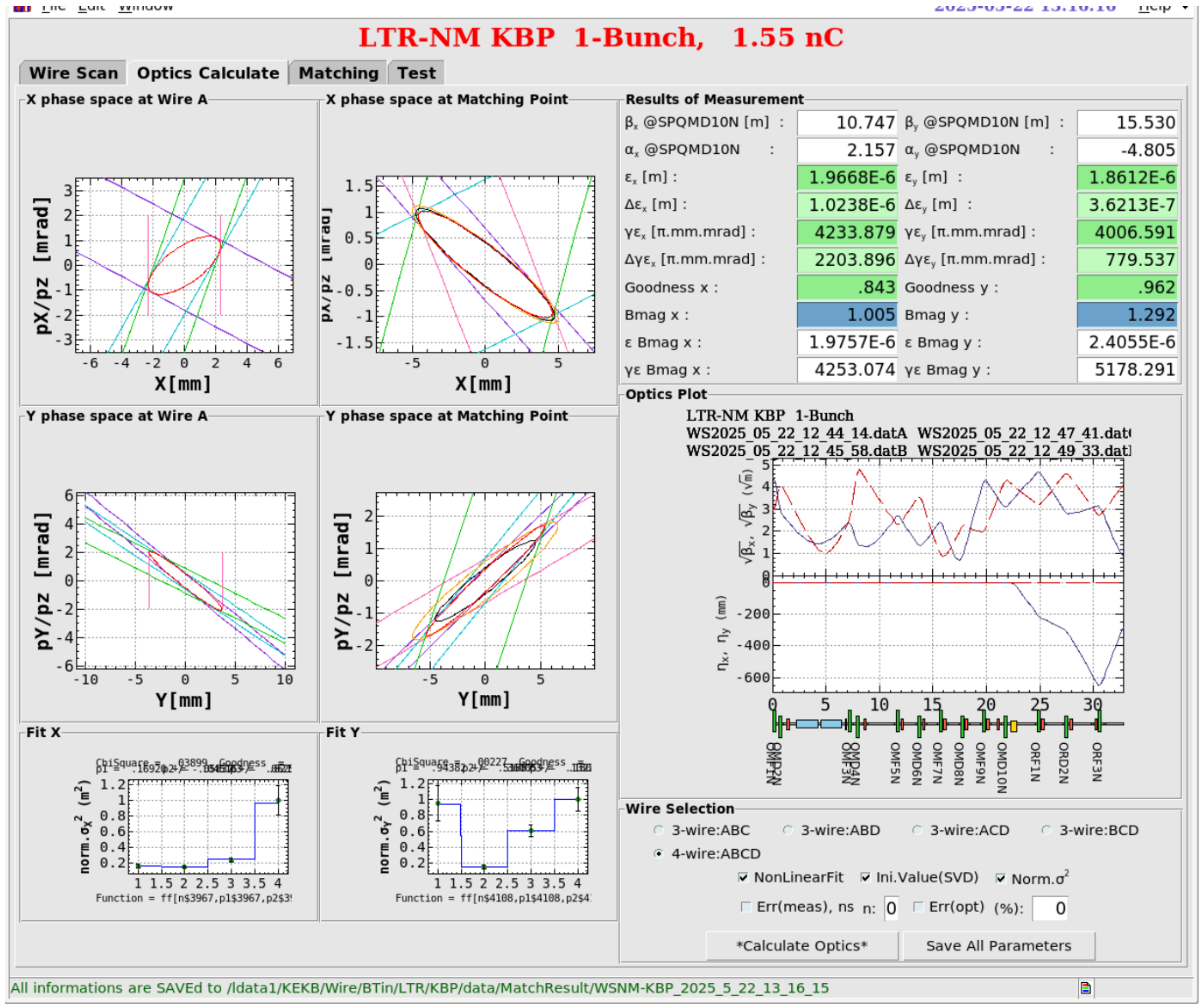
DESY.

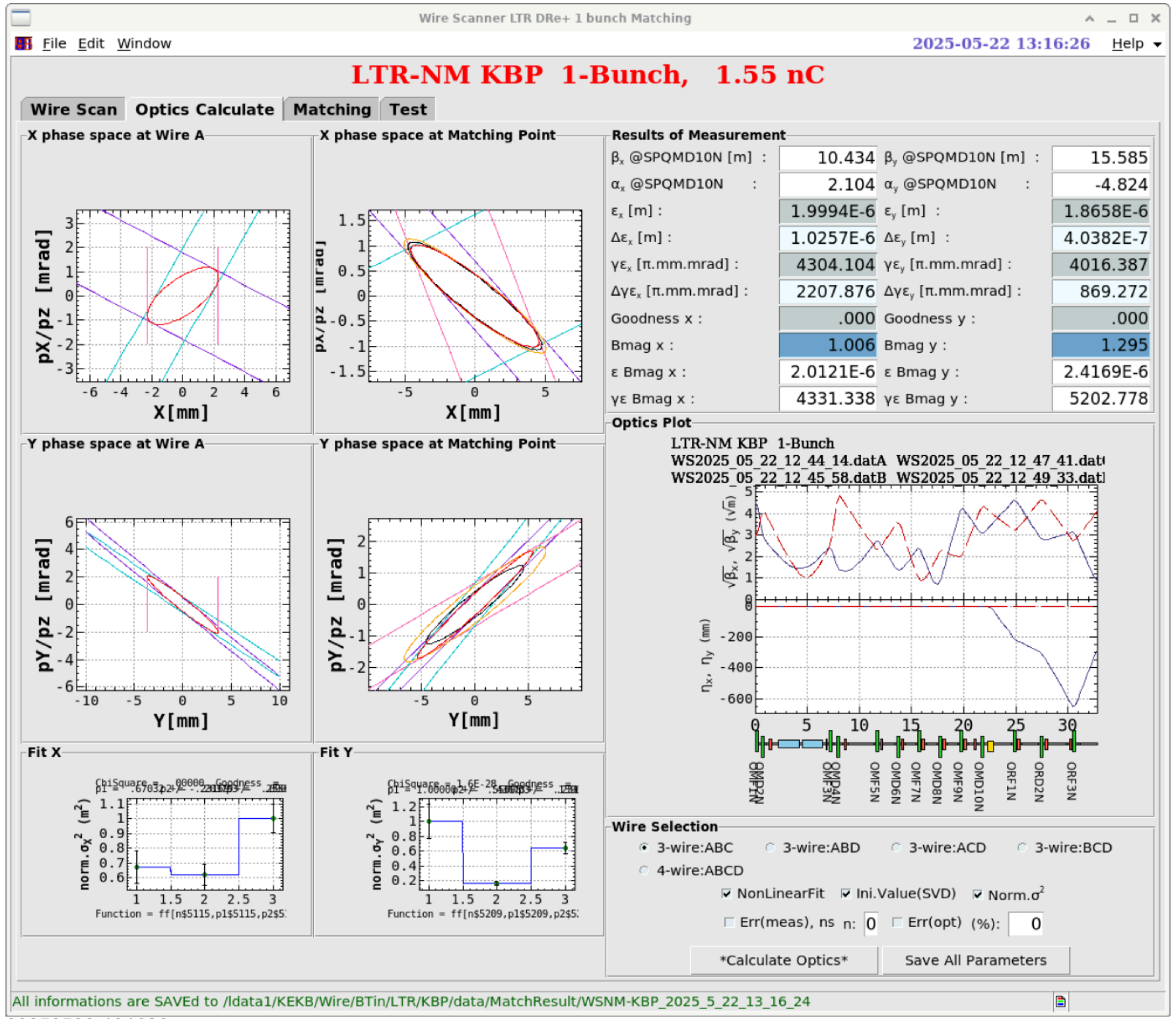
Measurements?

With wire scanners: LAST MEASUREMENTS in operation log

	γ**e_y**	γ**e_x**	**charge**
BSECT	56.7	25.94	2.5
CSECT	42.113	64.084	2.8
2SECT			
LTR	54.8	58.5	
3sec	143.04		3.08
5sec	35.6	38.7	2.5
BT	72.3	111.4	

Optics calculated





DESY.